AIR DISPERSION MODELLING OF NO_2, PM_{10}, $PM_{2.5}$, METALS AND BENZO-A-PYRENE FROM DELIMARA POWER STATION

Draft Final Study Report

submitted to
Malta Environment Planning Authority

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ECOSERV'S REPORT REFERENCE: 097-11

August 2011

Executive summary

Scope: The Delimara Power Station operated by Enemalta Corporation is one of Malta's two large power generating plants. Delimara Power Station is situated on the Delimara peninsula inside Marsaxlokk Bay (Section 4.1). The study applies a range of numerical simulation models (Section 7) for air quality impact assessment for the Delimara Power Station, its planned capacity expansion, with and without the background emissions in a 15 km model domain around the plant.

Baseline: The plant emits from up to eight different stacks ranging from 150m to 30m in height on average (based on a combination of measurements, estimates, and the IPPC permit) about 140 g/s NO_x, and 50 g/s particulates. Estimated metal emissions are in the order of below 1 mg/hour and up to 20 mg/hour for nickel, or below detection limit (for B[a]P).

Measurements: Background real-time data was collected for particulate matter (PM10 and $PM_{2.5}$) over a continuous period of 4 weeks, and this was analysed using the gravimetric standard method. Samples collected for PM10 were also analysed chemically for the potential presence of the heavy metals cadmium, arsenic and nickel, and the organic compound benzo-a-pyrene, pollutants that can be potentially attributed to emissions from the power plant. Traffic count data were also collected from 2 locations (Birzebbugia and Marsaxlokk) over a representative 3-week period. Such measurements were used as part of the data sources of the modelling component.

Expansion: Under worst case assumptions, and assuming full operational load, the planned capacity extension from 305 to 450 MW will lead to an increase in emissions, estimated as: NO_x: 34 g/s (+25 %); PM_{10}: 25 g/s (+50%) presumably reflecting the different efficiencies of pollution control measures (selective catalytic reduction and bag filters for the expansion scenario), increases in the emissions of metals and B[a]P assumed parallel to the particulates with + 50% (Section 7.2).

Model based analysis: The impacts (ambient ground level concentrations on regular receptor grids, individual sensitive receptor locations, and computed as population exposure) has been computed by several numerical air quality simulation models, combining (regulatory) Gaussian models, Eulerian dynamic 3D codes, and a Lagrangian model (Section 7.). The models were run for a set of nested domains (from European to local), and for the main annual impact scenario for a 15 km domain with the Delimara Power Station located in the SE quadrant. A primary impact zone (defined by a 6 km radius circle around the Delimara Power Station, was also used).

Other sources: Background emissions from all other sources in the domain come primarily from the second power plant at Marsa, harbor operations (Valletta and Malta Freeport), the Malta International Airport, a range of smaller commercial sources and traffic. Together, these sources contribute 168 g/s NO_x and 58 g/s PM_{10}, traffic is estimated at 32 g/s NO_x, annual average (section 4.2).

Baseline scenario (Section 7.1): With these emissions, the plant in its baseline configuration is in compliance with the air quality limits and target values as defined in Directive 50/2008/EC[1].

Capacity expansion (Section 7.2): Also with the capacity expansion, the plant by itself is in compliance with all annual limits and target values, and meets the short-term (hourly for NO_2 and daily for PM_{10}) requirements from Directive 50/2008/EC.

Background alone:

- Point and area sources: Emissions from background sources are predicted to cause exceedances of the short-term air quality standards
  - for NO_2 (compared to simulated NO_x)
  - PM_{10}

- Line sources (road traffic): Traffic scenarios have been simulated with a 10m resolution for those days (24 hour model runs) where the background any of the scenarios have predicted the highest concentration or numbers of violations of the hourly NO_2 limit value.

  Traffic by itself (given the simplified road network and short-term traffic frequency observations used to estimate annual average and patterns) causes numerous exceedances of the hourly standards; these exceedances are very local (close to the roads at a 10m receptor grid); when aggregated to a 100 m resolution, the exceedances "disappear" due to the steep, local concentration gradients, but contribute to the overall background in a larger area.

Combined scenarios:
Combining the DPS emission with the background to a total of approximately 360 g/s NO_x (long-term average), of which less than 10% are estimate to come from traffic based on the available observations data), will obviously also lead to at least as many exceedances. The key question addressed is whether the capacity expansion will lead to a change in the compliance situation.

Overall Compliance (Sections 8 and 10):

1. The DPS by itself, with or without capacity expansion, does not violate any air quality standards defined by Directive 50/2008/EC;

2. The background sources are predicted to violate the short-term air quality standards for NO_x (hourly) more often than the maximum number of annual exceedances granted in Directive 50/2008/EC (18 times for NO_x);

[1] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on Ambient Air Quality and Cleaner Air for Europe

3. The combined (cumulative impacts) scenarios of DPS with capacity expansion together with the background emissions do not lead to significant additional violations of limit or target values as defined in Directive 50/2008/EC. The expected increase in the frequency of hourly NO_2 violation varies from 0.3 to 3.8 %, which is well below the inter-annual variability.

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Abbreviations and Acronyms

BaP	Benzo-a-Pyrene
DPS	Delimara Power Station
EC	European Communities
ECE	Economic Commission for Europe
EMEP	European Monitoring and Evaluation Programme
GIS	Geographical Information System
HFO	Heavy Fuel Oil
http	hypertext transfer protocol
IPPC	Integrated Pollution Prevention and Control
km	kilometer
MEPA	Malta Environment & Planning Authority
MPS	Marsa Power Station
MW	MegaWatt
NCEP	National Centers for Environmental Prediction
NO_2	Nitrogen Dioxide
NSO	National Statistics Office
PAH	Polycyclic Aromatic Hydrocarbon
PM_{10}	Particulate matter, .LE. 10µm
$PM_{2.5}$	Particulate matter, .LE. 2.5µm
SCR	Selective Catalytic Reduction
LTO	Landing Take Off Cycle
TPS	Thermal Power Station

2. Introduction

The Delimara Power Station (DPS), operated by Enemalta Corporation is one of Malta's two large power generating plants. The DPS is situated on the Delimara peninsula inside Marsaxlokk bay. The current operations at DPS (305 MW total capacity) are expected to increase through a 144 MW extension to a new total capacity of 449 MW. Dispersion modeling of NO_2, PM_{10}, $PM_{2.5}$, metals (cadmium, arsenic, nickel) and benzo-a-pyrene (BaP) is therefore required to estimate the likelihood of any exceedances of the limits laid down in the legislation (Directives 2008/50/EC on ambient air quality) from the proposed new operations (under various operational conditions), especially but not limited to the most sensitive receptor(s) in the prevailing wind direction.

The Delimara plant is regulated by an IPPC permit (IP 0002/07/A), which places limits on the concentration of emissions to air arising from this plant. The IPPC permit also requires that the dispersion of NO_2, PM_{10} and $PM_{2.5}$ be studied through a dispersion model, to estimate the likelihood of there being any exceedances of the relevant limits laid down by Directives 2008/50/EC and Directive 2004/107/EC, especially but not limited to the most sensitive receptor(s) in the prevailing wind direction. MEPA also considers it important for emissions of metals (cadmium, arsenic, nickel) and BaP from the current operations at DPS to be modeled.

The Malta Environment and Planning Authority (hereafter 'MEPA') issued a call for tenders entitled "Air Dispersion Model of NO_2, PM_{10}, $PM_{2.5}$, Metals and Benzo-a-pyrene from Delimara Power Station", hereafter referred to as "the Tender", on the MEPA website on the 1st April 2010. A joint bid for this tender was submitted by Environmental Software & Services GmbH and Ecoserv Ltd (hereafter ESS & Ecoserv). Further to the contract signed by MEPA and ESS & Ecoserv, dated 17 February 2011, this offer for air dispersion monitoring was accepted as per conditions published in the call for tenders and as described in our tender submission.

The overall objective of the services sought under this project is to assist MEPA in assessing, using dispersion models, the likelihood of current and future emissions from DPS causing exceedances of the limit and/or target values for NO_2, PM_{10}, $PM_{2.5}$, metals (cadmium, arsenic, nickel) and BaP in Directives 2008/50/EC and 2004/107/EC, especially but not limited to the most sensitive receptor(s) in the prevailing wind direction. The dispersion models also needed to take into account emissions from other local sources (e.g. traffic). Emissions from the future extension at DPS must be modeled under different operational conditions.

Current average emissions (estimated/calculated) from the 305 MW (fired with a mixture of heavy fuel oil and gasoil, respectively), as described in the IPPC permit (parts A, B) made available by MEPA are shown in Table 1. The particulate estimates are derived from hourly emission monitoring from the DPS stacks.

Nota bene: The measured NO_x emissions as reported by ENEMALTA exceed these original estimates by a factor of 2, with a total of 138 g/s.

Table 1. Current average emissions from the DPS

Pollutant emittted	kg/year	g/s
Nitrous oxide, N_2O	3,000	0.1
Oxides of Nitrogen, NO_x	2,367,000	75.06
Sulphur dioxide, SO_2	6,310,000	200.09
Particulates (PM_{10})	390,936	12.37
Particulates ($PM_{2.5}$)	no data	no data
heavy metals		mg/s
Arsenic, As	34	0.95
Cadmium, Cd	10	0.30
Chromium, Cr	22	0.70
Nickel, Ni	168	5.33
Lead, Pb	39	1.24

3. Scope of work.

Work performed under this contract includes:

1. Compilation of relevant meteorological and air quality monitoring data, GIS data including road network and population distribution, compilation of emission data from related sources including Marsa Thermal Power Station (TPS), Marsa Thermal Treatment Facility (MTTF), ports in Valletta and Delimara, Malta International Airport, road network and residential areas. All data have been imported in a consistent, geo-referenced data base with on-line interactive display and analysis functions.

2. Dispersion models covering NO_2, PM_{10}, $PM_{2.5}$, cadmium, arsenic, nickel and BaP, emissions from both the current operations at DPS and proposed operations at DPS under various operational scenarios to estimate the likelihood of there being any exceedances of the relevant limit/target values. The impact assessment considers population exposure in a 15 km domain around the DPS, including an inner 6 km radius, and considers the long-term wind distributions for the years 2008, 2009, 2010 including the most sensitive receptor(s) in the prevailing wind direction (receptor points)

3. Interpretation and summary of the results, i.e., the absolute and relative difference between ambient concentrations and impacts (ambient concentration in the model domain, compliance, exposure at receptor points, population exposure).

4. The final output is presented as text, tabular statistical analysis, and in a range of topical maps indicating ambient ground level concentrations, color coded, exceedances, maxima, etc. including contour plots. Relevant scenarios (baseline, extension, w/o background, NO_x, PM_{10} and metals where relevant), underlying data sets (meteorology, monitoring, emissions) as well as the real-time model system (EUREKA WEBAIR) are available on-line leading to full resolution imagery and interactive display options for registered users.

5. These results are being presented in this report which also includes an executive summary.

6. Presentation of the methodology and results to MEPA, the operators of the installation being modeled and members of the public.

4. Site description

4.1 Delimara TPS location

The Delimara power station (DPS) is located at the South-Eastern part of the main island of Malta in the vicinity of Marsaxlokk Bay; the reference location for the primary emission source for the purpose of the models is 460016, 3965719 (UTM zone 33s, ED50).

4.1.1 The Delimara Power Station

The DPS is a "Combustion installation with a rated thermal unit exceeding 50 MW", and licensed for the generation of electric energy through the combustion of HFO and gasoil. The baseline system is described in the IPPC Permit IP 0002/07/A[2].

Baseline configuration:
The baseline configuration includes the release points (stacks or chimneys) outlined in Table 2.

Table 2. Baseline configuration emission points

stack	boiler	UTM X	UTM Y	MWTh	height	diam.	temp.	m3/s	m/s	NO_x g/s
D1	DSP1	460,038	3,965,822	331	150	2.9	165	65	7.14	64.66
D2	OCGT1	459,869	3,965,745	121	16	3.5	560	138	12.5	0.51
D3	OCGT2	459,881	3,965,727	121	16	3.5	560	138	12.5	1.92
D4A	CCGT3	460,088	3,965,766	121	30	3.2	560	138	14.1	6.67
D4B	main/bp	460,072	3,965,789		66	3.2	170	138	13.7	23.50
D5A	CCGT4	460,037	3,965,731	121	30	3.1	560	138	14.1	22.64
D5B	main/bp	460,021	3,965,754		66	3.2	170	138	13.7	18.17
SUM				815						138.6

average efficiency 37.5 % = 305 MW el.

Extended configuration:
The extended configuration includes the additional boilers and stacks (two flues/stack) outlined in Table 3.

Table 3. Extended configuration emission points

stack	boiler	UTM X	UTM Y	MWTh	height	diam.	temp.	m3/s	m/s	NO_x g/s
D6A	DPS61/2	460,133	3,965,689	77	65	2.1	170	66		0
D6B	DPS63/4			77		2.1	170			0
D6C	DPS65/6	460,101	3,965,665	77	65	2.1	170	66		0
D6D	DPS67/8			77		2.1	170			0
SUM				308						

average efficiency 46.8 % = 144.14 MW el.

Note: the 0 NO_x emission from the new 8 diesel generators would have to based on a 100% efficiency of the SCR system, also applies to the other pollutants

[2] Permit number IP 0002/07/A Integrated Pollution Prevention and Control Regulations (LN 234 of 2002) as amended by LN 230 of 2004 and LN56 of 2008

(particulates and metals) covered by the bag filter system. More realistic Extension Scenarios have been calculated assuming total additional emissions of 34 g/s NO_x or 8.5 per stack, and 25 g/s particulates, see section 7.2.

Specific emissions (NOx, g/s and thermal MW) are shown in Table 4. The table shows an extreme variance of normalized emissions estimates over more than two orders of magnitude.

Table 4. Specific MW and NOx emissions

MW (thermal)	NO_x g/s	g/s and MW
331	64.66	0.195
121	0.51	0.002
121	1.92	0.016
121	30.17	0.249
121	40.81	0.337
815	138.07	0.169

4.2 Other emission sources

To compare the ambient air quality against the applicable target and limit values, emissions from other relevant sources have also to be taken into account to evaluate cumulative effects (see Figure 1 for an inventory of sources considered). Contact was made with the alternate emission sources below to obtain input data for the air dispersion model. Appendix A provides more information on the data and respective sources utilised in this study.

- Traffic: local major road network/traffic; to obtain current estimates, traffic counts (vehicle class specific) and parallel meteorological and air quality observations were performed at two locations (in both directions) in Birzebbugia and Marsaxlokk, on representative days over a 3-week period during May 2011.
- Residential traffic (based on census data obtained from NSO and local council boundaries)
- Marsa TPS: emission data for 2010 were provided by ENEMALTA
- Marsa Thermal Treatment Facility, emission data for 2010 provided by the operator WasteServ Malta;
- Valletta Harbour ship movements by type (2008-2010)
- Malta Freeport Monthly frequency of ships calling (2008-2010)
- Malta International Airport (LTO cycles, frequency and aircraft composition for the years 2006 – 2010)
- Several smaller industrial and commercial sources close to DPS:
    - Oil Tanking Malta
    - San Lucjan Oil Company
    - 31st March 1979 Fuel storage (ENEMALTA)
    - Wied Dalam Depot

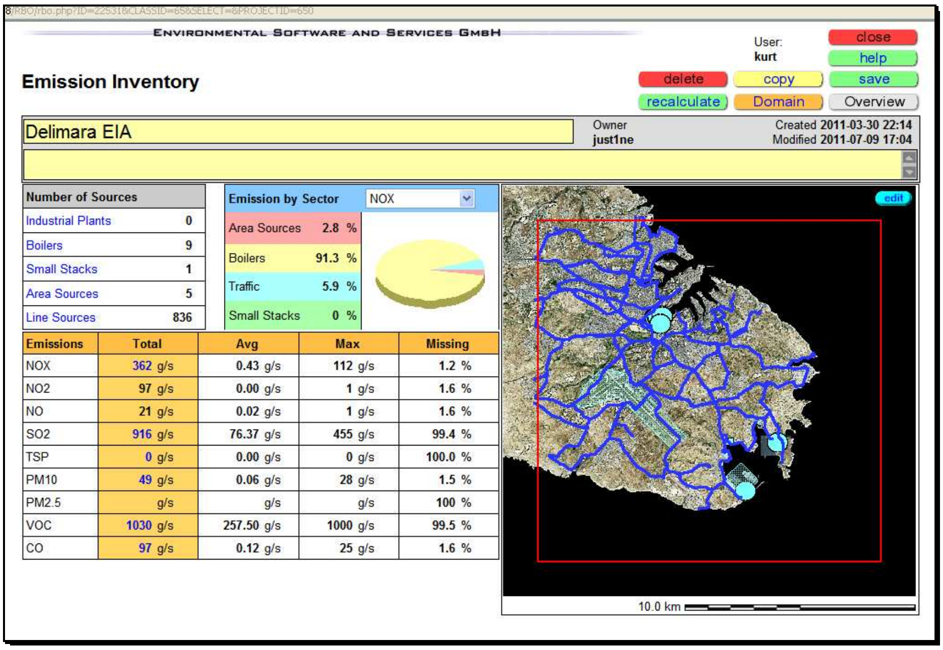


Figure 1. Inventory of emissions sources considered.

4.2.1 Traffic observations and emissions

Traffic counts (one hour with 15 minute resolution) were conducted

- o at two locations (both directions monitored separately), Birzebbugia and Marsaxlokk, three times each at during May:
- o three days of the week, Wednesday (07-08), Friday (16-17), Sunday (11-12)

Table 5 shows the summary of frequencies (vehicles per hour, both directions added together) averaged over the three sampling events.

Table 5. Traffic frequency at Birzebbugia and Marsaxlokk

day	Birzebbugia	Marsaxlokk	Average
Wed	1,384	344	864
Fri	1,245	435	840
Sun	1,020	743	881
AVG	**1,216**	**507**	**861**

With the differences between the two observations points significant (factor of 2.4), and the weekly pattern (weekday versus Sunday) opposite at the two locations, and the daily pattern insufficiently defined by three sampling hours, only the global average, deemed representative for the road class “Distributor” can be used without any further assumptions. In addition, yet without any observed evidence, we assume that while the observed average is representative for the period from 07:00 – 17:00 a generic daily (24 hour pattern) can be assumed that with linear interpolation, reduces the traffic intensity before 07:00 and after 17:00 with a linear decay towards a minimum scaling factor of 0.2 times the average during work hours for the period from 00:00 – 04:00. No annual (monthly) pattern can be determined from a single observation, so we assume traffic to be constant throughout the year. Table 6 shows the scaling factors attributed to each road class.

Table 6. Scaling factors allocated to the three main road classes

road class	scale	N/h
trunk, arterial	1.11	956
primary, distributor	1.00	861
secondary, rural	0.32	276

Other than vehicle frequency, average speed, fleet composition, and cold-start fraction have to be known or assumed to estimate vehicle emission using EEA COPERT emission factors.

Fleet composition: Table 7 illustrates the fleet composition that was derived from the traffic observations. Aggregated into four categories, passenger cars clearly dominate the fleet with almost 90%. The class Heavy Duty Vehicles (HDV) includes buses.

Table 7. Traffic fleet composition derived from traffic observations

class	motorcycles	cars	LDV	HDV
%	1.4	89.4	6.8	2.4

A range of emission standards from pre-ECE to EURO-3 are assumed. Passenger cars are assumed to be predominantly gasoline based with an average engine size of 1.6 ltr, and an average speed of 60/50/40 km/h depending on road type. Figure 2 illustrates the fleet composition, derived from the observed vehicle classes at Marsaxlokk and Birzebbugia, which is used for COPERT v.8 classification. The fleet is dominated by 90% passenger cars (assumed to be 84 % gasoline and 5% diesel powered) and is used as the basis for traffic emission estimates.

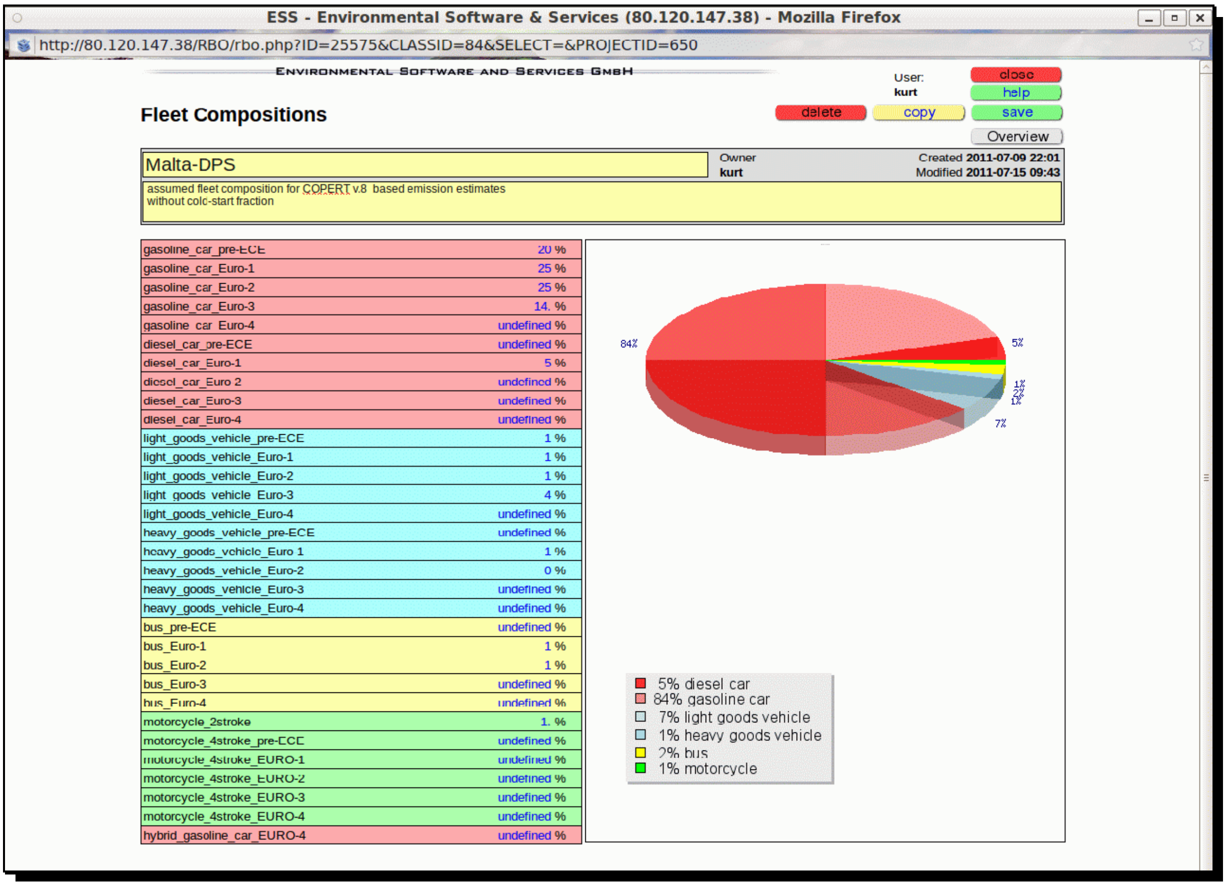


Figure 2. Traffic fleet composition used as basis for traffic emissions estimates.

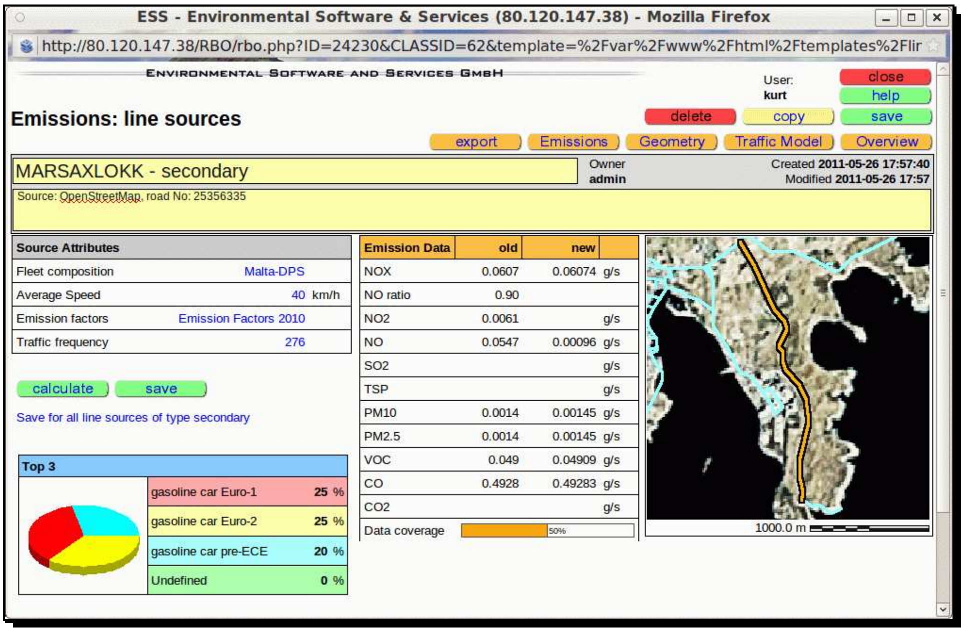


Figure 3. Line source emissions are taken into account on a secondary road in Marsaxlokk.

4.2.2 Air quality observations, background

Within the 15 km DPS model domain, air quality observations were made available by MEPA for the monitoring stations at Zejtun and Kordin and a background station outside the domain in Gharb, Gozo (Figure 4). Additional air quality observations were conducted at the two stations associated with the traffic observations in Marsaxlokk and Birzebbugia (Figure 4). The observed air quality values are summarized by substance in Tables 8, 9,10 and 11 below.

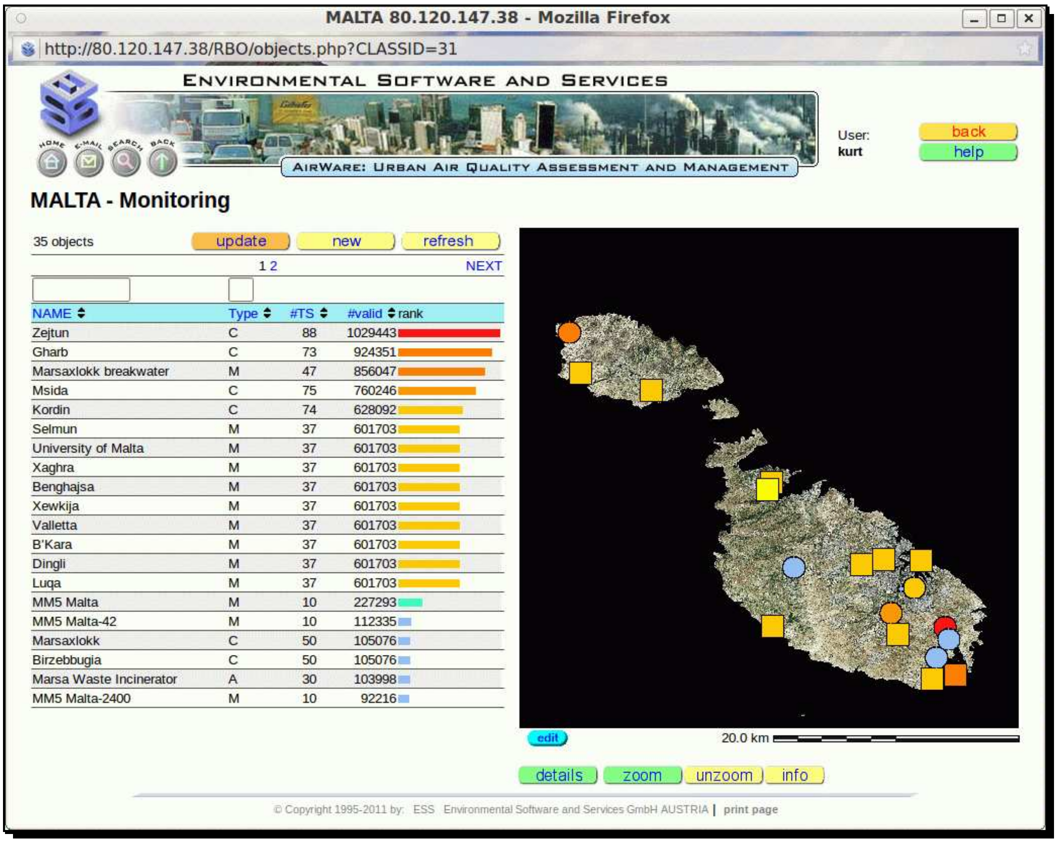


Figure 4. Map showing locations for sources of air quality data: (i) MEPA background air quality monitoring stations: Zejtun (red circle), Kordin (yellow circle) and Gharb, Gozo (orange circle). (ii) Stations at which air quality observations and data were collected by Ecoserv at Marsaxlokk and Birzebbugia monitoring stations (blue circles) .

Table 8. NO_x and NO_2 hourly values.

Monitoring station	avg. µg/m^3	max. µg/m^3	N of obs.	from	to
NO_x hourly					
Zejtun	36.45	651.05	2,842	01/01/2008	05/31/2009
Kordin	88.99	235.32	787	01/01/2008	05/31/2009
Gharb (background)	2.90	58.80	11,126	01/10/2008	05/31/2009
NO_2 hourly					
Zejtun	35.10	332.60	2,842	01/01/2008	05/31/2009
Kordin	13.30	27.70	787	01/01/2008	05/31/2009
Gharb (background)	4.50	58.40	11,126	01/10/2008	05/31/2009

Table 9. PM_{10} hourly, PM_{10} daily and $PM_{2.5}$ daily values.

Monitoring station	avg. µg/m^3	max. µg/m^3	N of obs.	from	to
PM_{10}, hourly					
Zejtun	26.00	1,581.00	8,111	01/01/2008	05/31/2009
Gharb (background)	33.00	1,276.00	7,681	01/10/2008	05/31/2009
PM_{10}, daily					
Marsaxlokk	54.10	154.00	29	18/04/2011	16/05/2011
Birzebbugia	70.00	250.00	29	18/04/2011	16/05/2011

$PM_{2.5}$, daily	**annual average target value (20100101) : 25.0 µg/m³**				
Marsaxlokk	52.70	149.00	29	18/04/2011	16/05/2011
Birzebbugia	34.7	61.00	29	18/04/2011	16/05/2011

Table 10. Heavy metals daily values.

Monitoring station	**avg. ng/m³**	**max. ng/m³**	**N of obs.**	**from**	**to**
Arsenic (ng/m³)	**annual average target value (20121231) : 6.0 ng/m³**				
Marsaxlokk	3.00	11.00	29	18/04/2011	16/05/2011
Birzebbugia	6.30	13.00	29	18/04/2011	16/05/2011
Cadmium (ng/m³)	**annual average target value (20121231) : 5.0 ng/m³**				
Marsaxlokk	0.10	1.70	29	18/04/2011	16/05/2011
Birzebbugia	0.70	2.50	29	18/04/2011	16/05/2011
Nickel (ng/m³)	**annual average target value (20121231) : 20.0 ng/m³**				
Marsaxlokk	4.60	29.00	29	18/04/2011	16/05/2011
Birzebbugia	3.30	18.00	29	18/04/2011	16/05/2011

Table 11. Benzo-a-pyrene below detection limit.

Monitoring station	**avg. ng/m³**	**max. ng/m³**	**N of obs.**	**from**	**to**
Benzo-a-pyrene (ng/m³)					
Marsaxlokk	ND[3]	ND	7	20110418	20110516
Birzebbugia	ND	ND	7	20110418	20110516

[3] ND - Not Detected

4.3 Model domains

The impact assessment simulations for the DPS (see Figure 5 for example) are run with a set of nested model domains. The model domain for the meteorological driving conditions covers a total of three nested levels.

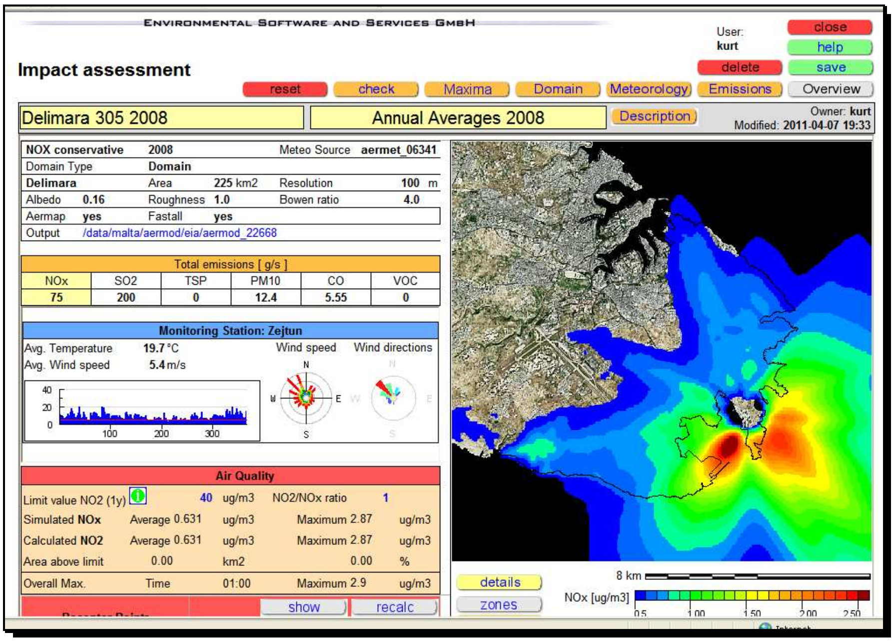


Figure 5. Impact assessment simulation for NO_x levels in 2008.

The model domain for air quality starts at the European (EMEP) level with 2,400 km, an intermediate level around Malta with 240 km (including the Southernmost part of Sicily), the Maltese islands with a 40 km box, and finally the local DPS domain with an extent of 15 km to account for dynamic boundary conditions and the impacts of long range transport for the use of the Eulerian model. For the innermost model domain (15 km square, see Figure 6), an additional 6 km radius circle around the plant has been introduced to define an inner impact zone.

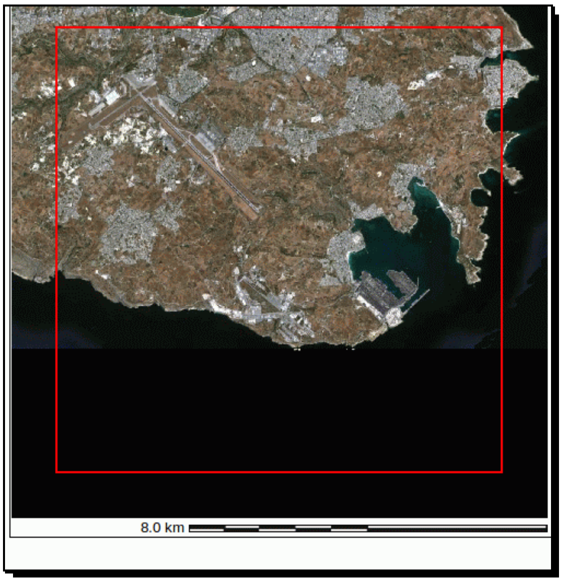


Figure 6. Local Delimara Power Station domain

For the estimation of emission/dispersion from the airport (3D LTO modeling) a specific domain was defined with an extent of 10 km, including the flight path up to 1,000 m elevation (limit of the LTO definition).

For the meteorological data (MM5 dynamic downscaling of NCEP-FNL and GFS data), a three level nesting is used (domain definitions below) with a final diagnostic interpolation to a 1 km resolution.

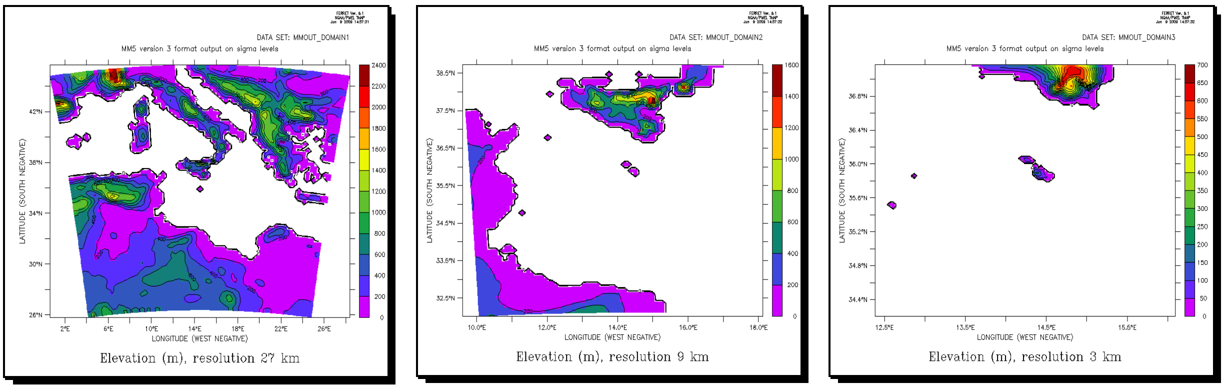


Figure 7. MM5 nested meteorological model domains with 27, 9 and 3 km resolution

5. Methodology

5.1 Air Quality Parameter Monitoring

Monitoring for air quality parameters at Birzebbugia and Marsaxlokk as per Task A4 of the Tender was initiated on the 18 April 2011 and continued until the 17 May 2011. Monitoring was carried out at the two stations identified in Figure 8.

Ecoserv's laboratory report reference for the data gathered on ambient air quality parameters is **097-11**. Sample reference codes are as follows:

- PM_{10} filters Marsaxlokk **A-125-11 to A-160-11**
- PM_{10} filters Birzebbugia **A-161-11 to A-196-11**
- $PM_{2.5}$ filters Marsaxlokk **A-197-11 to A-231-11**
- $PM_{2.5}$ filters Birzebbugia **A-232-11 to A-266-11**

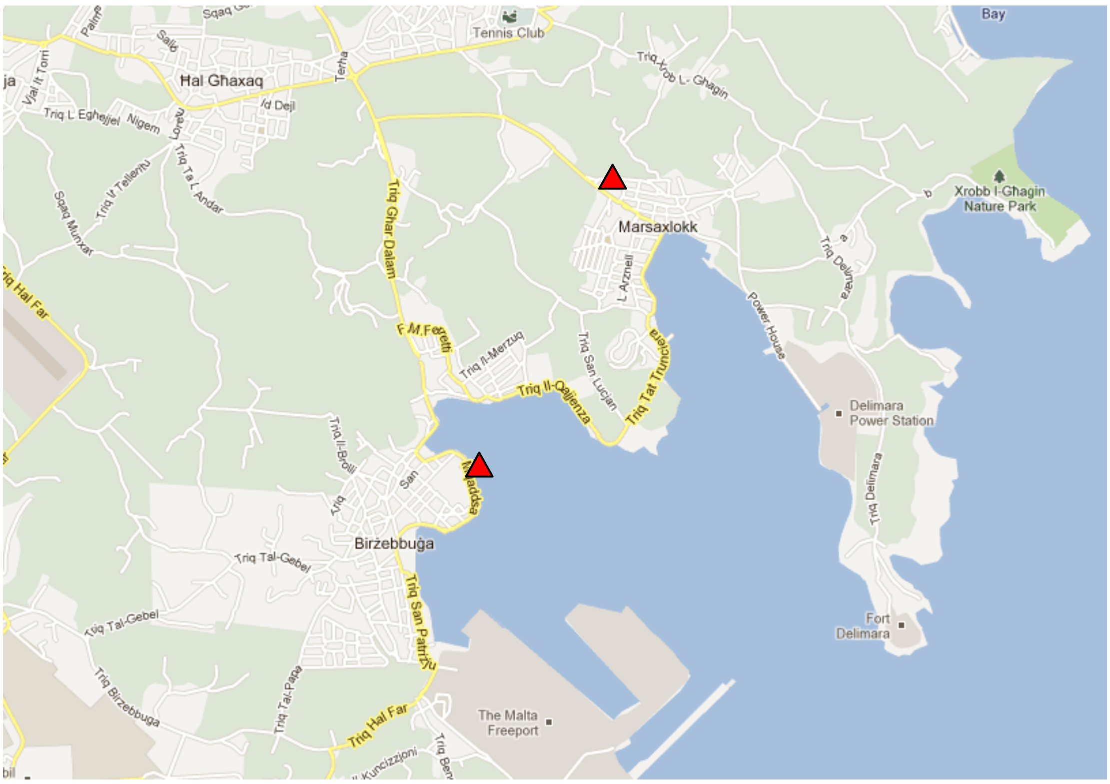


Figure 8. Air parameter monitoring stations (red triangles) in Birzebbugia and Marsaxlokk.

Data was collected according to standards specified in Directives 2008/50/EC and 2004/107/EC. 24-hourly filter samples were collected, for the parameters specified in Table 1, during the measurement period. Meteorological conditions, including precipitation, wind direction and strength, were also recorded during the sampling period. Appropriate control measures, such as the taking of blanks, were ensured throughout the period of sampling and analysis. Table 12 specifies the methodologies and detection limits employed by CADA Laboratories s.n.c., accredited according to ACCREDIA[4] CEN/ISO 17025:2005 certification (Accreditation number 0439).

Table 12. Air Quality parameters monitored, with respective standard methods and detection limits.

Parameter	Standard method	Limits of detection
PM_{10}	DM n°60 02/04/2002 SO GU n°87 13/04/2002 + UNI EN 12341:2001	0.01 µg/m^3
$PM_{2.5}$	DM n°60 02/04/2002 SO GU n°87 13/04/2002 + UNI EN 12341:2001	0.01 µg/m^3
Cadmium (in PM_{10})	UNI EN 14385:2004	1.5 ng/m^3
Arsenic (in PM_{10})	UNI EN 14385:2004	2 ng/m^3
Nickel (in PM_{10})	UNI EN 14385:2004	8 ng/m^3
Benzo(a)Pyrene (in PM_{10})	DM 25/08/2000 GU n°223 23/09/2000 All 3	0.3 ng/m^3

5.2 Traffic emissions data methodology

The response to Tender by ESS and Ecoserv specified the use of available data on traffic counts and traffic fleet composition. Data on traffic counts and fleet composition at Birzebbugia and Marsaxlokk was gathered after it was established that traffic count data was not available, and MEPA have agreed that data collection can be affected at 2 locations in the vicinity of the air quality monitoring stations.

The stations at which traffic counts were held are identified in Figure 9. In the case of traffic counts gathered at Birzebbugia, the final traffic count station was established following discussions with MEPA regarding traffic diversions on site due to road works.

[4] ACCREDIA Italian Accreditation System is the National Accreditation Body in Italy

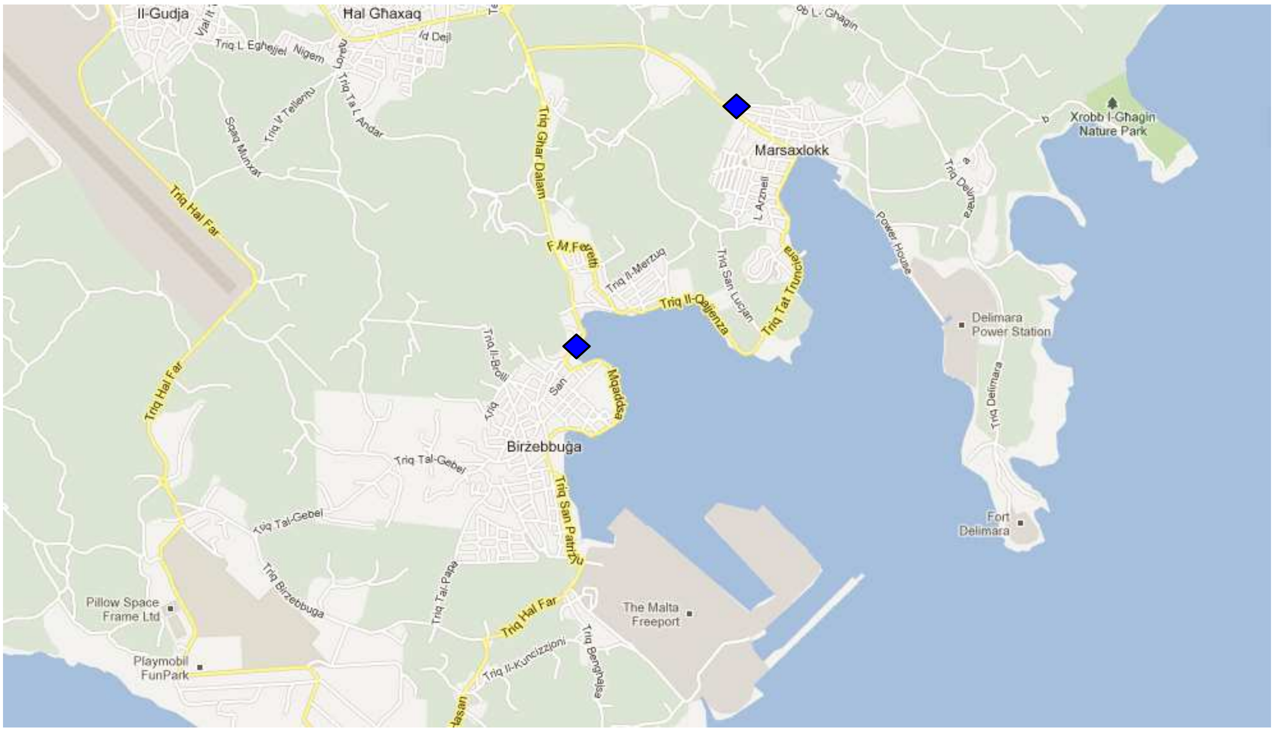


Figure 9. Traffic count locations (blue diamonds) in Birzebbugia and Marsaxlokk.

5.3 Dispersion model methodology

The primary method employed is simulation based impact assessment. This consists of the following basic steps:

- Compilation of a reasonably complete and consistent data base of meteorological driving conditions (preferably for several years
- Compilation of corresponding emission data from the primary and nearby located emission source;
- Compilation of all relevant monitoring data for the test period.
- Compilation of basic site specific data such as Digital Elevation Model (DEM), land use, administrative boundaries (census tracts), road network, sensitive receptor points)
- Simulation and evaluation of the baseline situations for both the primary emission source only and in combination with all other emission that may influence the model domain (compliance with ambient air quality standards).
- In addition to the simulation of the DPS within the basic 15 km model domain, individual source classes were separately simulated with different models at very high resolution:
    - TRAFFIC with a modified (mixing zone) version of AERMOD adapted for line sources with a computation kernel, low-pass filter representation of the mixing zone, and a convolution method to efficiently simulate larger road networks (10 m grid resolution, hourly steady state assumption)

  - PUFF (Lagrangian model with Gaussian (multi-)puffs) for mobile sources (airport, aircraft LTO; 10 m resolution, 100 ms computational time step, hourly scaling and aggregation);
- Annual scenarios for the DPS w/o additional emissions with hourly resolution were run for the years 2008, 2009 and 2010 to document the effect with inter-annual meteorological variability (see also: Sensitivity analysis below); from the annual model runs (AERMOD AERMOD/OLM) episodes with predicted violations were selected for re-runs
  - AERMOD/ 24 hours to get detailed hourly results
  - CAMx for proper NO_2 photochemistry including dynamic boundary conditions; CAMx scenarios include at least one 24 hour period pre-processing for a “warm” mode start with calculated initial conditions.
- The model results are summarized in a number of indicators such as domain average, maxima, exceedances, average above threshold (standard), number and locations of exceedances, etc.
- Model validation, i.e., comparison with corresponding monitoring data.
- Sensitivity analysis, that determines the effect of several assumptions or model settings (such as resolution, simulation period, impact zone) on the model results
- Simulation and evaluation of the capacity extensions (an approximate 50% increase in the power generation capacity leading, however, to only marginal increases in emission due to advanced emission control technology for both the primary emission source only and in combination with all other emission that may influence the model domain (compliance with ambient air quality standards). The model results are summarized in a number of indicators such as domain average, maxima, exceedances, average above threshold (standard), number and locations of exceedences, etc.
- The results of the two cases (baseline versus extended capacity) are then compared and interpreted in terms of the absolute and relative change in expected air quality and compliance.

6. Identification of sensitive receptors

Model results (ambient concentrations) are calculated on a regular grid of receptor point with a model specific resolution down to 10 m (TRAFFIC, PUFF). In addition, a number of individual specific or sensitive receptor points (Figure 10) have been introduced to calculate ambient air quality values for these sensitive locations.

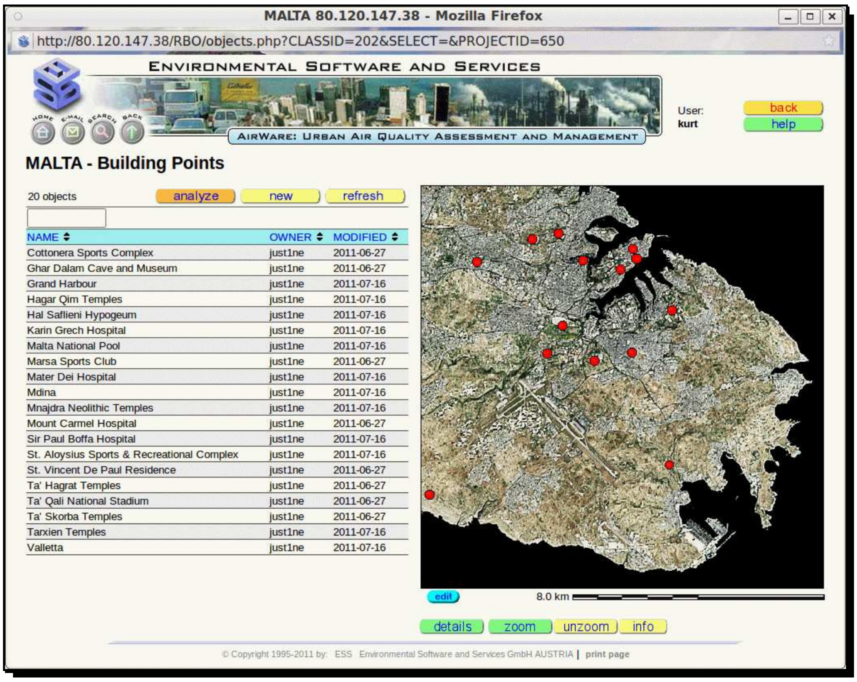


Figure 10. Receptor points identified as sensitive receptors.

6.1 A 6 km impact zone

According to the TOR, an impact zone (a circle with a 6 km radius) around the DPS plant location was introduced. For the model results, average and maxima within the circle, outside, and over the entire 15 km (square) model domain are computed and reported separately where appropriate.

6.2 Receptor points

For the 15 km DPS EIA domain, the sensitive receptor points identified in Table 13 have been implemented (model results extracted for these locations). For all model runs and scenarios, calculated concentrations at these locations are extracted as time series data and stored with the corresponding (virtual observation station) OBJECTS, summarized and displayed with the model scenario results.

Table 13. Receptor points considered as sensitive receptors. Ambient air quality results have been extracted for these locations.

Receptor name	type	GX	GY
Cottonera Sports Complex	public building	457,324	3971,118
Ghar Dalam Cave and Museum	public building	457,282	3966,157
Grand Harbour	UNESCO heritage	456,269	3972,739
Hagar Qim Temples	cultural heritage	449,676	3965,165
Hal Saflieni Hypogeum	cultural heritage	454,889	3969,477
Karin Grech Hospital	health care	454,555	3972,663
Malta National Pool	sports facility	453,785	3973,514
Marsa Sports Club	public building	453,847	3970,596
Mater Dei Hospital	health care	452,920	3973,361
Mnajdra Neolithic Temples	cultural heritage	449,616	3965,239
Sir Paul Boffa Hospital	health care	455,761	3972,409
St. Aloysius Sports & Recreational Complex	sports facility	451,183	3972,610
St. Vincent De Paul Residence	public building	453,364	3969,749
Tarxien Temples	cultural heritage	456,089	3969,746
Valletta	UNESCO heritage	456,126	3973,008

6.3 Population exposure

To estimate population exposure, data for 67 census tracts have been imported (polygon boundaries, calculated size, population numbers, derived density). For a more detailed geo-reference of population, the census tract data have been combined with CORINE land use, allocating the population to the built-up areas only. In addition, elevation distribution for each census tract was extracted from the underlying high-resolution (30 m) DEM.

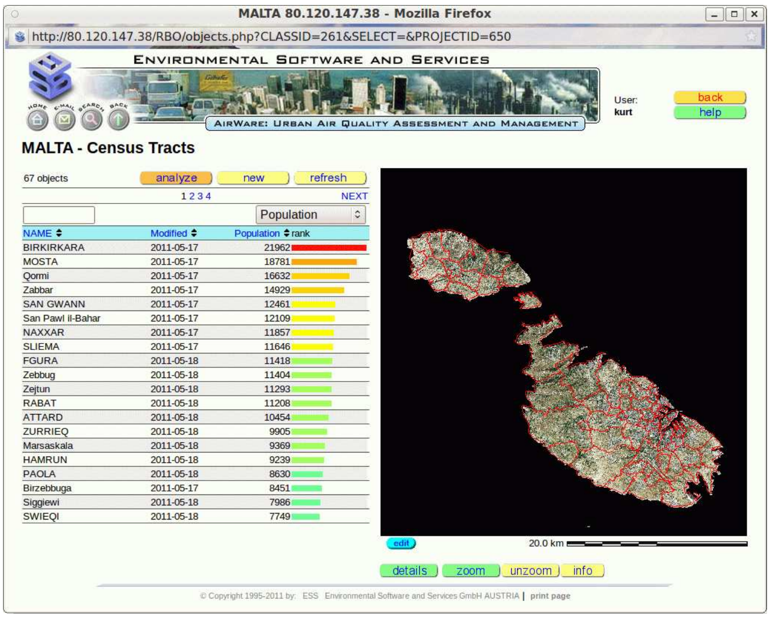


Figure 11. Census tracts used to distribute population numbers and estimate population exposure.

From the ambient concentration calculated by the models, areas (absolute and in % of the domain), and the population in these areas where the concentration exceeds the applicable standards, are computed and displayed in tabular form and on the map (red overlay).

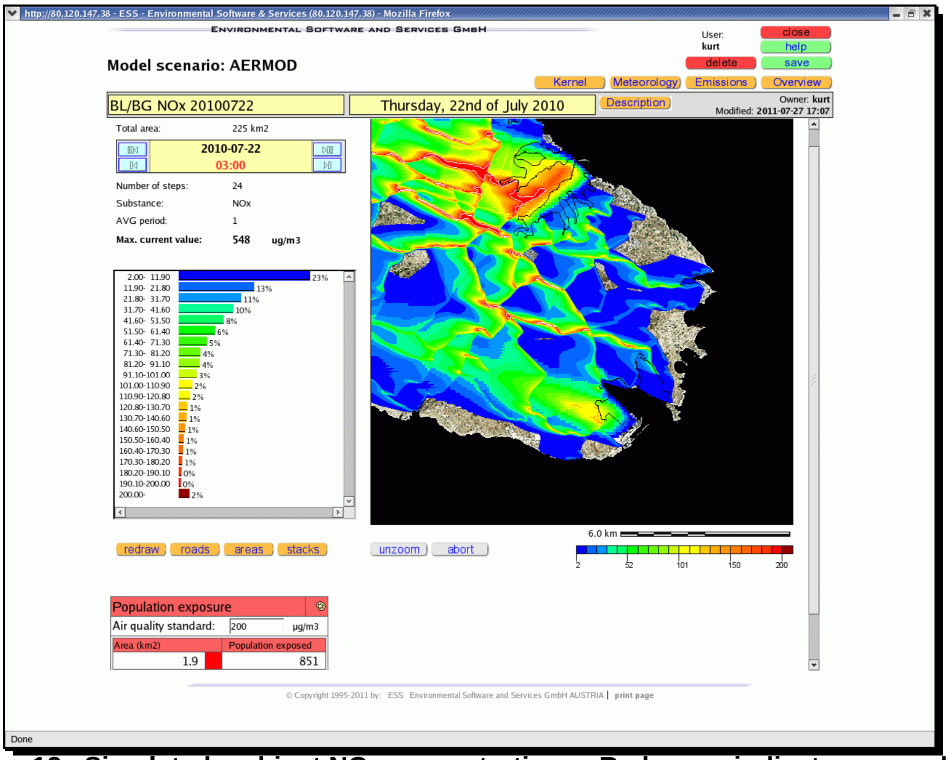


Figure 12. Simulated ambient NO_x concentrations. Red areas indicate areas where concentrations exceed the applicable standards.

7. Dispersion models

The dispersion model system (Figure 13) is part of an AirWare demo configured for Malta within the framework of EUREKA E! 3266 WEBAIR.

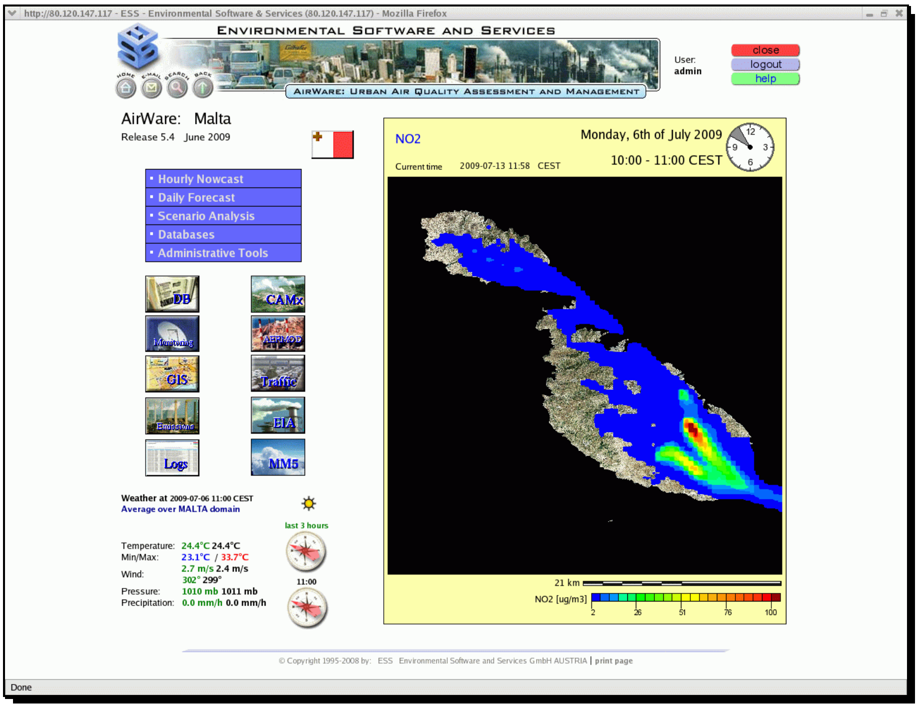


Figure 13. Dispersion model system configured for the study.

The dispersion model system includes the following:

– MM5 for the calculation of detailed, distributed (hourly, one km resolution) local meteorology, re-analysis run from NCEP GFS data sets, that include local meteorological data for data assimilation (objective methods);

– CAMx, nested grid Eulerian model including PM_{10}/$PM_{2.5}$, at hourly resolution for larger local domains (all of Malta, larger domain with both of the Power stations, interaction between Delimara and Marsa); CAMx will be run on an annual basis (hourly time step, 250 m resolution, and for several most common/worst case episodes of 5 days each at 100 m resolution;
AERMOD, regulatory Gaussian model, with arbitrary spatial resolution (possible display resolution on a regular grid down to 5 m or any number of arbitrarily located simulated monitoring points) but based on the assumption of a homogeneous and constant wind field for each run assumed to be in steady state; for a wind speed of 3 m/s, this makes a model domain to about 6 km downwind feasible for an assumed 1 hour averaging period; AERMOD/AERMET was run for annual results (on an hourly basis, i.e., 8,760 hourly model runs per year) to compute the averaging periods necessary. Table 14 illustrates averaging periods for PM_{10}, $PM_{2.5}$, BaP, and other metals

regulated, based on 2008/50/EC Annex XI, and the information available online at the following links

- o http://ec.europa.eu/environment/air/quality/standards.htm
- o http://ec.europa.eu/prelex/detail_dossier_real.cfm?CL=en&DosId=193497

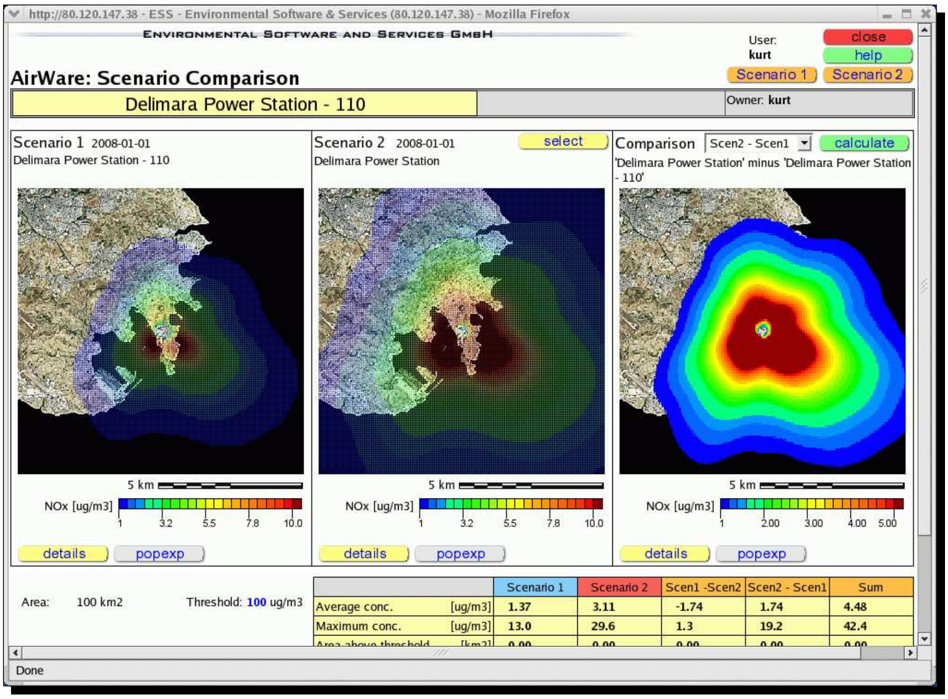


Figure 14. Scenario comparison in the AirWare model.

Particulates (PM_{10}) in AERMOD (current release version 09292) can be represented by either:

- Specifying up to 20 particulate size categories defined by average diameter, mass fraction and density;
- Defining the mass fraction below 2.5 micron, and the mean diameter in this class.
-

Please note that the particle size distribution definitions can be made independently for each PM_{10} source.

Table 14. Averaging periods for the air quality parameters taken into consideration in the dispersion model.

Substance	Averaging period
Nitrogen dioxide	One hour, calendar year
PM_{10}	One day
$PM_{2.5}$	Calendar year
As, Cd, Ni	Calendar year
PAH	Calendar year

– TRAFFIC, a Gaussian line source model derived from AERMOD, with the addition of a mixing zone representation to account for traffic induced turbulence over/along the road. The mixing zone has been implemented as a nested set of low-pass filters, which reduces (and re-distributes) artificial extremes produced by the Gaussian model close to the source.

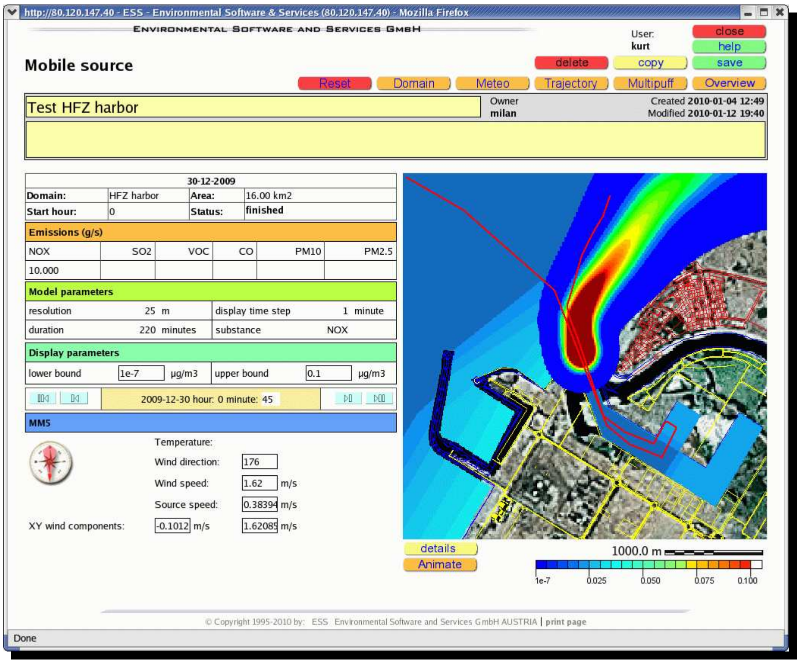


Figure 15. Mobile emission sources such as ship traffic are considered.

– INPUFF, a dynamic combined Lagrangian and Gaussian plume model with arbitrary resolution (down to 5 m) which depends, however, on the detail of the (diagnostic) wind field interpolation between 2 min, output time steps from MM5, interpolation from the 3 km resolution to 5 m, based on a roughness characteristics of surface, and a 30m spatial resolution DEM. INPUFF is run with a 1-5 minute output time step for short episode of 24 hours max, e.g., for the representation of highly transient meteorological conditions (sea breeze) or changing emission conditions (boiler startup phase). INPUFF can also be used for mobile sources such as large ships, entering, berthing for loading, and leaving a harbor.

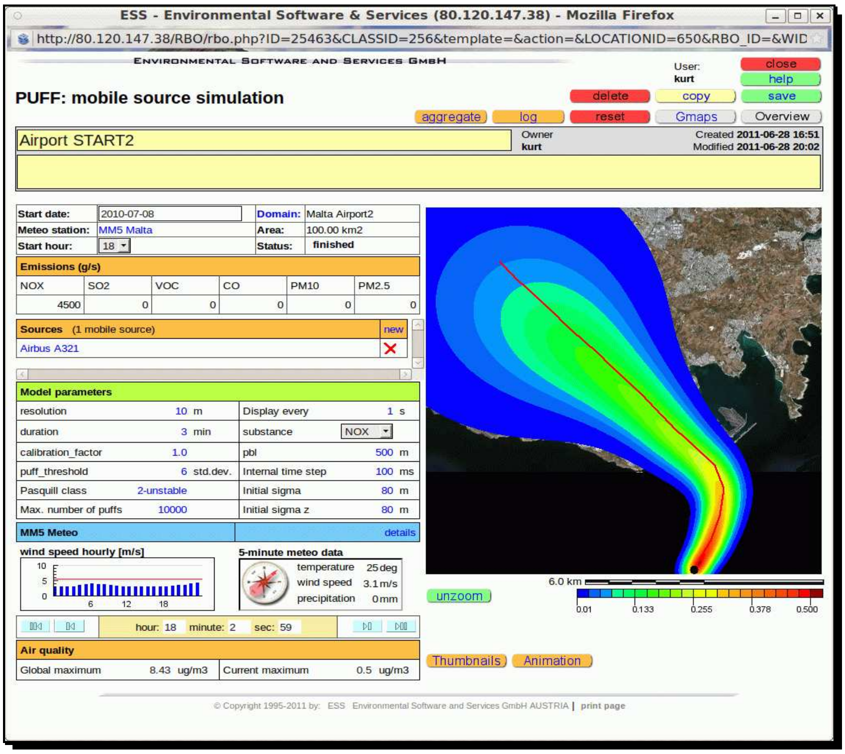


Figure 16. INPUFF model simulation for mobile marine traffic emission sources.

– a second version of INPUFF has been adapted for the airport, and the simulation of 3D flight paths at start and landing (LTO cycles). Here the model is run for individual events of a few minutes with a computational time step of 100 ms and a 10 m spatial resolution, which are then scaled and aggregated to account for the airport contribution to ambient air quality.

7.1 Model scenarios: meteorology and background

Model scenarios were run for

- three years of (model generated re-analysis) meteorology 2008, 2009, and 2010 (monitoring data and re-analysis methodology described below)
- several model/domain combinations around the basic DPS impact assessment domain of 15 km extent around the plant location;
- several emission scenarios:
    - o background emission sources in the 15 km domain including traffic (line sources) with a high-resolution (10m) convolution model
    - o DPS baseline with and without surrounding emissions
    - o DPS expansion under different assumption of the long-term average efficiency of the emission control technologies for the 8 new diesel engines (SCR, bag filters), with and without surrounding emission to calculate cumulative effects.

7.1.1 Shared Meteorology 2008 - 2010

The meteorological data used includes monitoring data from several stations. Observed and generated wind speed data is illustrated in Table 15.

Table 15. Wind speed data, observed and generated, from various monitoring stations.

Station name	**N of obs.**	**start**	**end**	**wind speed m/s**	
				average	max
observations					
Zejtun	25,357	20080101	20101231	3.7	16.7
Marsaxlokk	886	20110412	20110523	6.0	9.0
Birzebbugia	886	20110412	20110523	3.0	9.5
Gharb	99,193	20080101	20101231	5.6	30.2
Msida	11,827	20080101	20090531	2.5	12.2
MM5 generated					
Zejtun	26,305	20080101	20101231	5.1	19.5
Marasxlokk	2,064	20110416	20110712	4.8	15.7
Gharb	26,305	20080101	20101231	5.7	21.2
Marsaxlokk 10m	2,089	20110416	20110712	4.6	15.2
Marsaxlokk breakwater	22,106	20010101	20010712	5.1	19.6
Marsaxlokk breakwater 10m	22,490	20090101	20110728	5.6	21.2
Birzebbugia 10m	2,437	20110416	20110718	4.5	15.1

For the simulation models, to obtain a complete (and consistent, representative) wind field for a larger area, the 3D nested grid prognostic meteorological model MM5 was used for the dynamic downscaling of NCEP/FNL data for the years 2008, 2009, 2010 to hourly values at a 1 km (diagnostically interpolated from 3 km MM5 output). The most critical parameters are wind speed (Table 15) and wind direction (Figure 17) shown for the closest station, Zejtun, and Gharb (with the longest observation time series). The wind-roses show the frequency of wind direction (left panel), and the corresponding wind speed in each direction class, right panel.

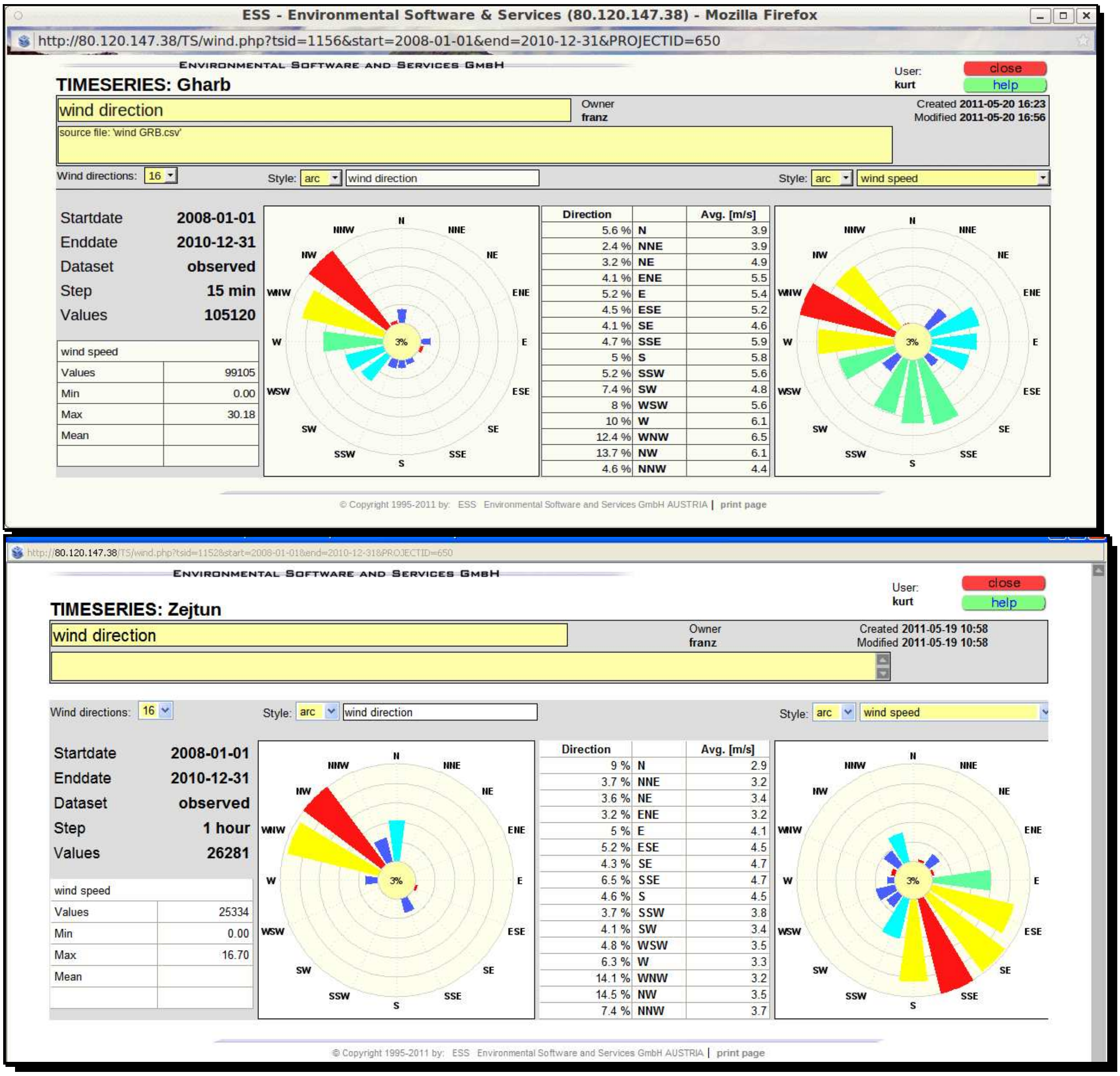


Figure 17. Wind direction (left panel) and corresponding wind speed (right panel) for Gharb (top) and Zejtun (bottom) monitoring stations.

The wind-rose for the station Zejtun (Jan.2008 to Dec. 2010, 26,281 hours) shows the distribution of wind direction (left), and the average hourly wind speed in each of 16 directional sectors. While the most common (frequent) wind is from NW, the strongest (fastest) winds can be expected from SE/SSE direction, i.e., from the sea.

7.1.2 MM5 model validation

The air quality scenarios are run alternatively with observation time series from the station Zejtun, or with model generated meteorological data sets, that are complete and consistent (they obey the conservation laws over the entire model domain, different from any individual observation point). Nevertheless, we demonstrate the re-analysis model performance is in direct comparison with the observation data (Station Zejtun, observation period: 2010).

While air pressure and temperature show near perfect agreement between observation and MM5-FNL re-analysis runs, the correspondence with the observations of wind speed and in particular wind direction are less exact, but still statistically highly significant (non-parametric correlations). The MM5-FNL runs have been used as the basis for the generation of the AERMET meteorological input files to drive AERMOD.

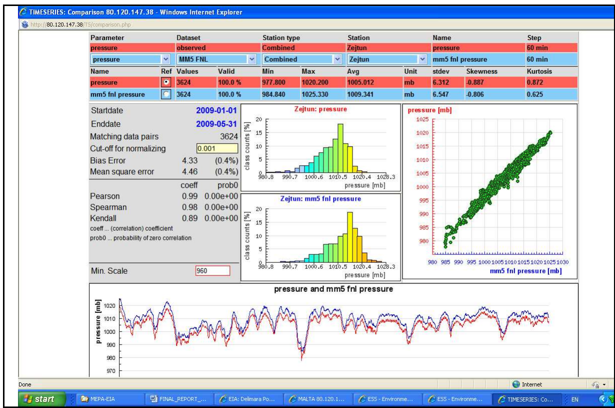


Figure 18. air pressure, observed vx MM5-FNL

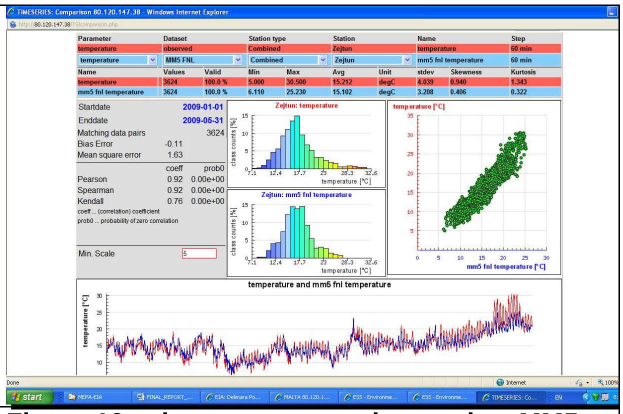


Figure 19. air temperature, observed vs MM5-FNL

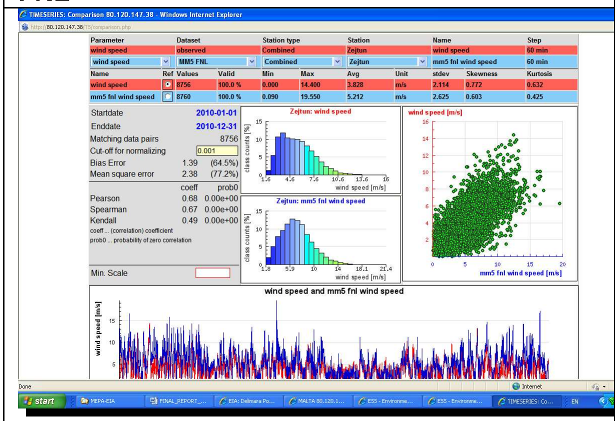


Figure 20. wind speed, observed vs MM5-FNL

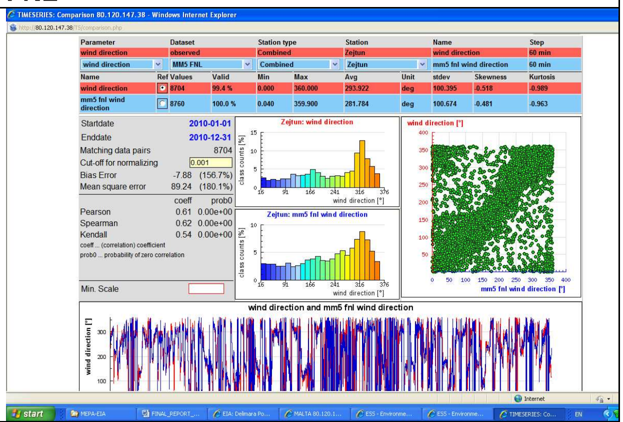


Figure 21. wind direction, observed vs MM5-FNL

7.1.3 Other emissions (background)

Other background emissions from point and area sources in the 15 km model domain contribute approximately 168 g/s NOx, and 58 g/s PM_{10}, roughly doubling the DPS emissions. Their respective contributions and impacts are itemized and summarized below. Emissions from traffic contribute approximately 32 gNOx/s.

Road network

A total of 839 road segments are included in the basic EIA model domain. The road segments are grouped in 3 classes, Table 16 specifies the associated assumptions and weights for the three main road classes. The emission estimates assume a constant fleet composition for the three road classes and a worst case scenario of constant traffic over 24 hours (no observations outside the period 07:00 to 17:00 are available); based on the traffic observation at the two points assumed representative for primary, distributor roads, the relative contribution of traffic in the impact assessment domain around DPS is estimated as 7.4% for NO_x.

Simulation of this highly simplified road network (Figure 22) at a 10 m (local) resolution, already indicates frequent violation of the hourly NO_2 standard (simulated as NO_x). However, the violations are concentrated North of the DPS 6 km radius primary impact zone.

Table 16. Road class weight factors and associated model assumptions.

road class	weight factor	avg.(km/h	NOx g/s/km
trunk, arterial	1.11	60	0.206
primary, distributor	1.00	50	0.186
secondary, rural	0.32	40	0.061

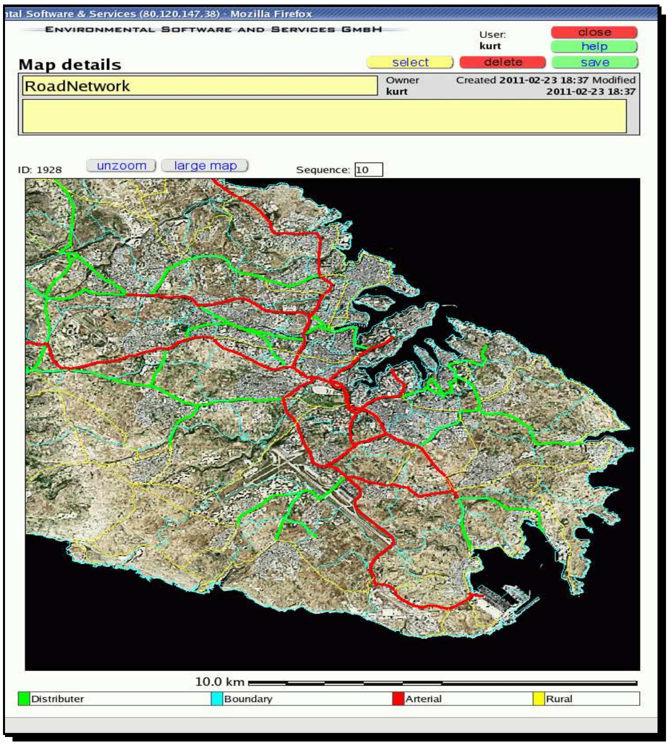


Figure 22. Road network considered in the modelling exercise.

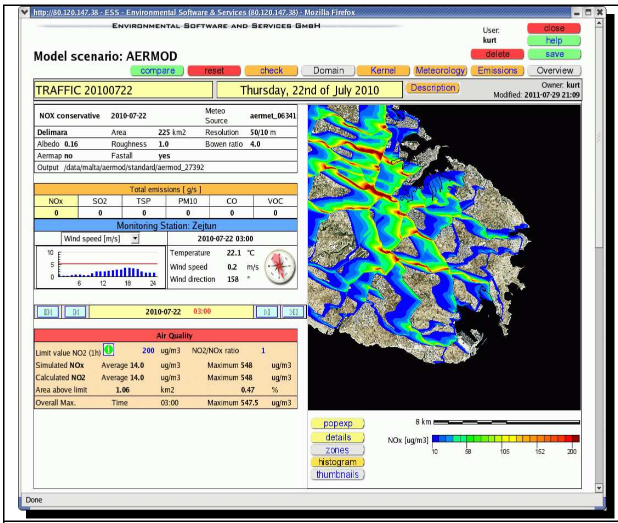


Figure 23. NO_x, hourly, nearfield (10 m resolution)

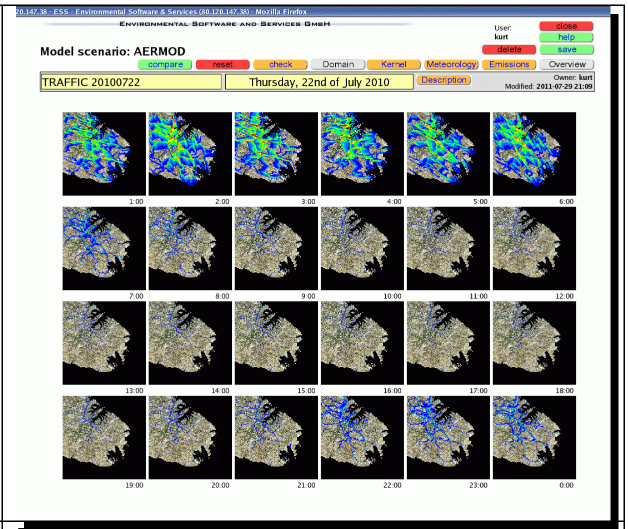


Figure 24. 24 hour thumbnails for 20100722, showing string variations with wind speed

Malta International Airport

Flight movements (start or landing) average out to 28,000 a year, or about 14,000 LTO cycles per year. Assuming an Airbus A320 as a representative and relatively modern aircraft type, this leads to a total emission of NO_X of 20 kg/LTO (based on the average over the 19 most common aircraft types, EMAP-EEA - 1.A.3.a.aviation_updates December 2010) total annual emission amount of 280 tons of NO_x or about 8.8 g/s (assuming continuous flight operations. Individual take-off scenarios (amounting to about 60% of the LTO cycle) have been simulated with a 3D Lagrangian model (INPUFF derived) at a 10 m resolution, with a 100 ms computational time step, up to an elevation of 1,000 m (LTO ceiling).

Marsa Power Station

Average emissions data (provided by ENEMALTA) derived from stack measurements were used in this modelling study (Table 17). Average NO_x emissions for the Marsa power plant amount to 143 g/s.

Table 17. Emissions data for Marsa Power Station

Stack/boilers	NOx g/s	stack (m)
Marsa, M1, boiler 3 &4	19.57	52.0
Marsa, M2, boiler 5&6	39.52	52.0
Marsa, M3, boiler 7	43.67	75.0
Marsa, M4, boiler 8	30.00	75.0
Marsa, OCGT	10.0	30.0
MARSA TPS TOTAL	142.76	

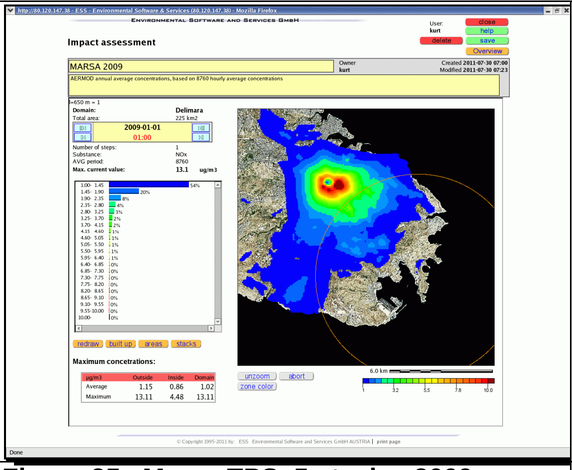


Figure 25. Marsa TPS, 5 stacks, 2009; annual compliance both inside and outside the 6 km impact zone.

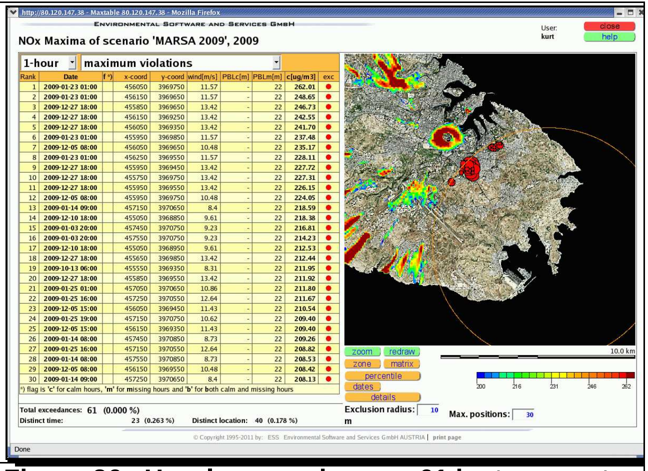


Figure 26. Hourly exceedences: 61 instances at the Northern edge of the DPS 6 km impact zone (a maximum of 18 exceedences/year are allowable according to 2008/50/EC)

Malta Thermal Treatment Facility:

Emissions data for the Marsa Thermal Treatment Facility was provided by WasteServ Malta. Emissions average out at 0.330 g/s NO_x which appears low, but would be negligible compare to the power plant emissions.

Harbors and ports:

The two harbors in the 15 km model domain, Malta Freeport and Valletta, report an approximate frequency of ship visits of 900/year (total) and 270/year (with a LOA of 90 m or more) respectively, each. Assuming a total of 1 hour of emissions at average cruise speed (speeds in the immediate vicinity and inside the harbor will be lower; the docking operations will take less time but involve bursts of full power) at an approximate emission rate for NO_x of 10 g/kW-hr (USEPA emission factors) result in average (combined) NO_x emissions of around 4 g/s.

The total NO_x emissions of the DPS and background sources (including a few smaller industrial/commercial sources) amount to about 170 g/s when taken together. 85% of these emissions can be attributed to the Thermal Power Station at Marsa.

Depending on a number of emission relevant assumptions (necessary due to lack of specific emission data for all additional sources), these sources combined contribute another 168 g/s of NO_x emissions to the DPS baseline emissions of 138 g/s to a total of just above 300 g/s NO_x in the 15 km DPS model domain. However, the resulting impacts (at ground level) also depend on emission height, as well as the assumptions on mixing height elevation development during the day and (reflectance/permeability) properties, for which no data are available.

Resulting model runs (with a 10 m resolution for the traffic sources) yield NO_x estimates (hourly maxima) of up to 226 µg/m^3; these maxima area attributable to traffic (Figure 27), and are mainly predicted outside the 6 km impact circle around the DPS, close to Valletta where the road density is higher.

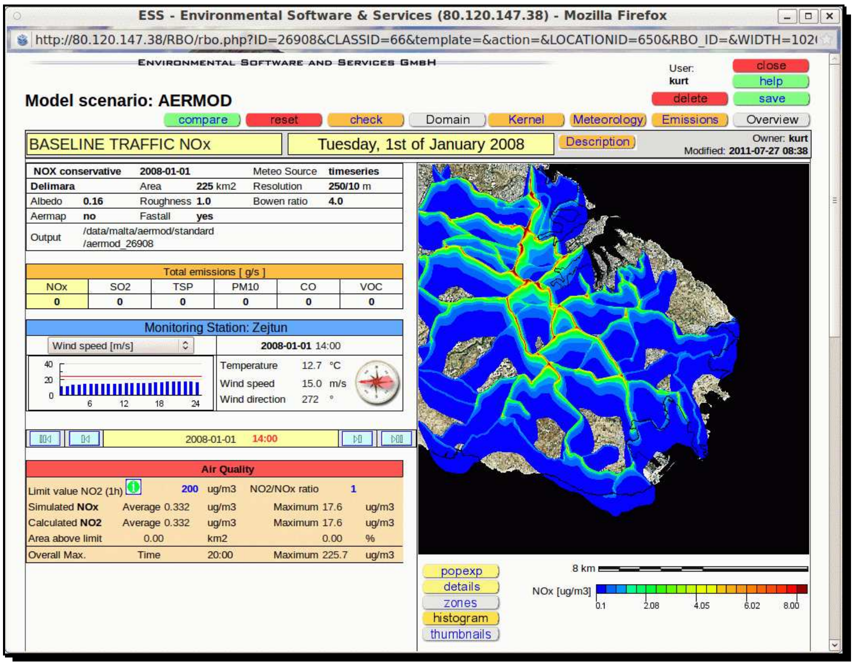


Figure 27. NO_x maxima attributed to traffic outside the 6km impact zone

The example below demonstrates the variability of predicted concentrations over a 24 hour cycle (depending on the choice of meteorological input data), with the observed maxima related to the predicted (AERMET) mixing height in the evening. The second example (same date) shown below uses a different data set with the AERMET data derived from MM5 re-analysis runs that generate consistent vertical temperature distribution and turbulence estimates. While the basic patterns are identical, the predicted maxima (near-field, close to the roads with a 10m receptor grid resolution) are 95.7 µg/m^3 and 225.7 µg/m^3, respectively.

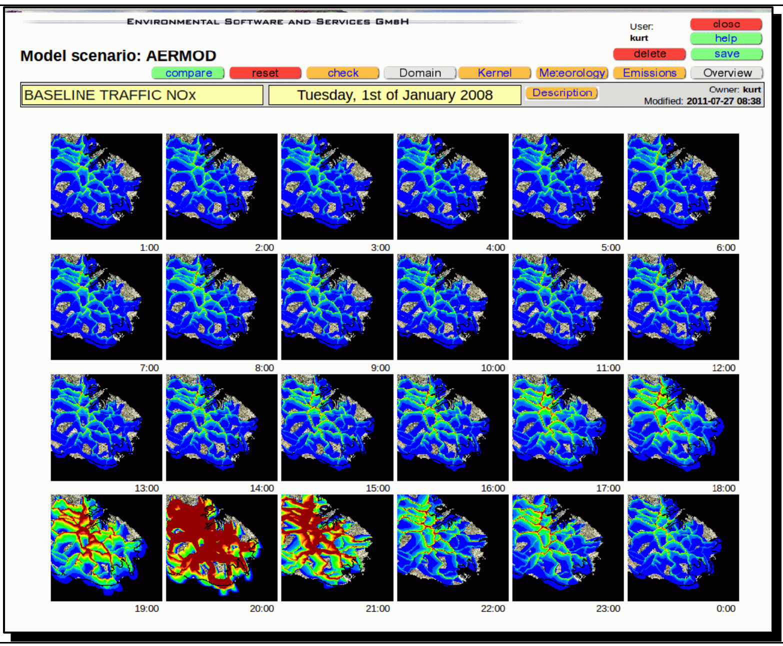


Figure 28. 24 hours, Jan. 01, 2008, on Zejtun meteorology; max. NOx: 225.7 µg/m^3

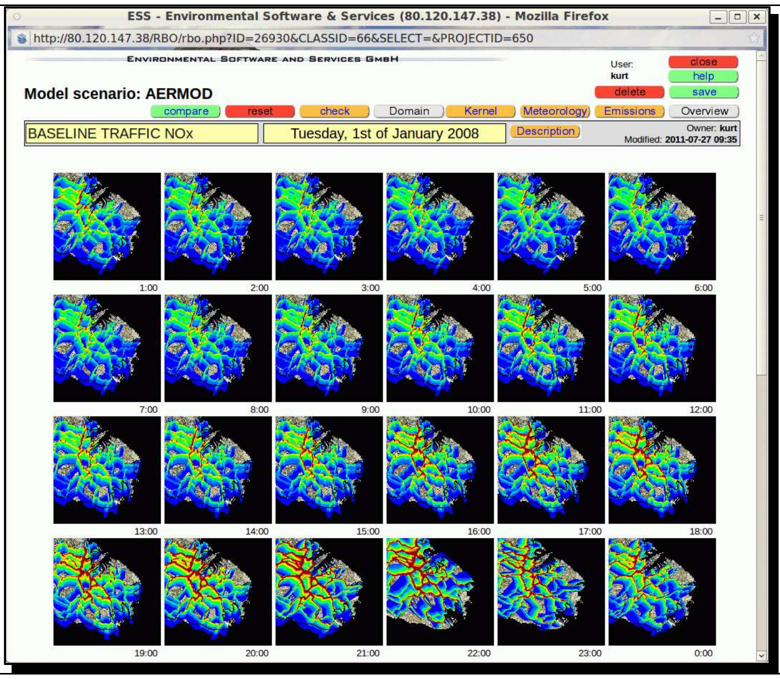


Figure 29. 24 hours, Jan.01 2008, AERMET from MM5-FNL, max. NOx: 95.7 µg/m^3

Table 18 below summarises the combined impact on ambient concentrations from background emission sources, calculated as 8760 hourly steady-state results (AERMOD/AERMET with AERMAP terrain correction).

- Annual limit and target values: the predicted concentrations are in compliance with Directive 50/2008/EC.
- NO_2, hourly standard: the model runs for background emission (without traffic) are indicating violations of the NO_2 hourly standard above the number of 35 allowable exceedences/year
- PM_{10} daily limit: no exceedances above the number of 18 allowable exceedances/year.

The values in Table 18 indicate the number of violations on a 100 m (hectar) grid of receptor points.

Table 18. Number of violations for other emissions (background emissions only, excluding traffic) on a 100m grid of receptor points.

Other emission sources (background)	total exceedances		distinct times		distinct locations	
	6km	15km	6 km	15km	6km	15km
NO_x/NO_2 hourly 2008	39	9,627	21	373	29	2,992
NO_x/NO_2 hourly 2009	74	13,777	34	2,141	49	2,107
NO_x/NO_2 hourly 2010	110	15,100	46	2,127	81	2,233
AVERAGE 2008-2010	74	12,835	34	1,547	53	2,444
PM_{10} daily 2008	1	4	1	4	1	2
PM_{10} daily 2009	0	4	0	3	0	4
PM_{10} daily 2010	0	6	0	3	0	5

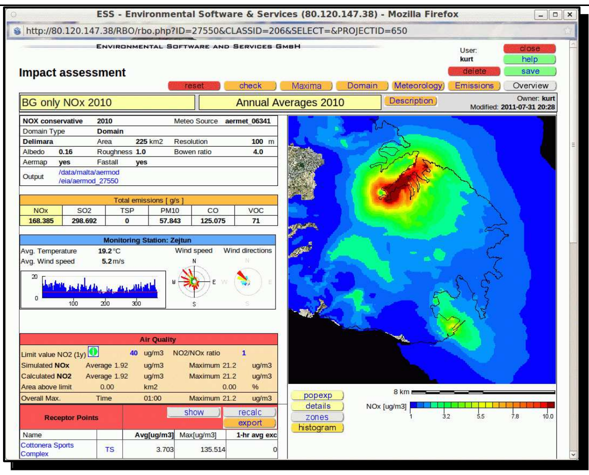


Figure 30. NO_x, 2010: background: annual average (in compliance)

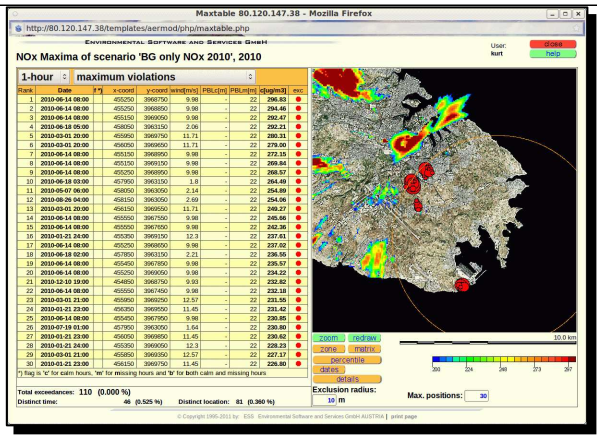


Figure 31. NO_x, 2010: background: hourly exceedances (2,127 hours or 24.3% of the year)

7.2. DPS baseline scenarios

For the baseline, emissions from the DPS was set to 138 g/s NO_x, derived from the actual DPS operations (stack monitoring data for 2009 01 01 to 2011 06 13, total of 16,870 hourly values) , and using all 8 individual stacks. The model was run with meteorology for the years 2008, 2009 and 2010 (alternatively directly with the monitoring time series and AERMET files generated from the MM5 FNL re-analysis runs (section 7.1 above).

7.2.1 Baseline scenarios, NO_x, DPS emissions only

Baseline 2008: Delimara 305 MW,
8 individual stacks, 138 g/s NO_x;
Meteorology: AERMET 2008, (extracted from MM5 re-analysis runs for the station: Zejtun)
Resolution: 100m, 8760 hourly runs.

Annual average maximum: 1.40 µg/m3
Hourly maximum: 120.53 µg/m3

Compliance: (simulated NO_x vs NO_2 standards)
annual standard : in compliance
hourly standard : in compliance

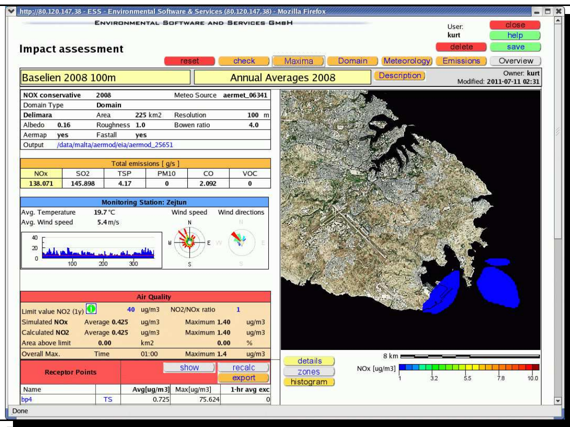


Figure 32. Baseline 2008:

Baseline 2009: Delimara 305 MW,
8 individual stacks, 138 g/s NO_x;
Meteorology: AERMET 2009, (extracted from MM5 re-analysis runs for the station: Zejtun)
Resolution: 100m, 8760 hourly runs.

Annual average maximum: 5.51 µg/m3
Hourly maximum: 142.59 µg/m3

Compliance: (simulated NO_x vs NO_2 standards)
annual standard: in compliance
hourly standard: in compliance

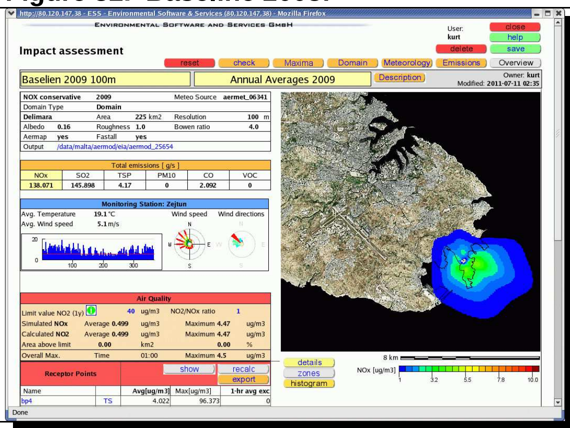


Figure 33. Baseline 2009

Baseline 2010: Delimara 305 MW,
8 individual stacks 138 g/3 NO_x;
Meteorology: AERMET 2010, (extracted from MM5 re-analysis runs for the station: Zejtun)
Resolution: 100m, 8760 hourly runs.

Annual average maximum: 3.84 µg/m3
Hourly maximum: 131.70 µg/m3

Compliance:
annual standard: in compliance
hourly standard: in compliance

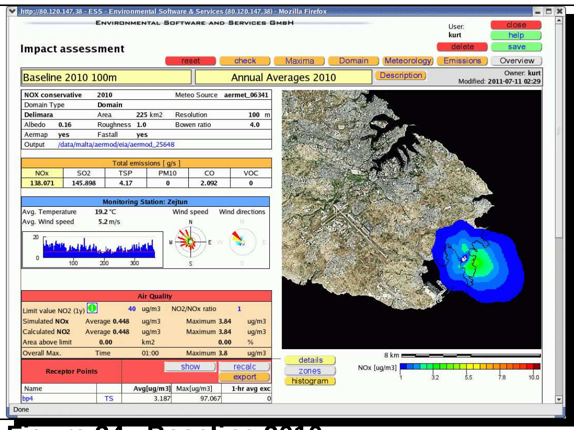


Figure 34. Baseline 2010

The results for these six baseline runs document the inter-annual variability due to meteorological conditions. The three annual baseline runs (8640 hourly steady state solutions with AERMOD and direct observation time series) are summarized below:

Baseline 2008: Delimara 305 MW,
8 individual stacks, 138 g/s NO_x;
Meteorology: Zejtun observations,
Resolution: 100m, 8760 hourly runs.

Annual average maximum: 13.90 µg/m3
Hourly maximum: 145.98 µg/m3

Compliance: (simulated NO_x vs NO_2 standards)

annual standard : in compliance
hourly standard : in compliance

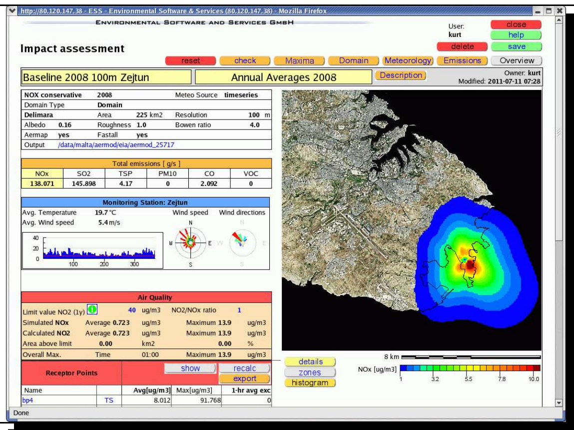


Figure 35. Baseline 2008

Baseline 2009: Delimara 305 MW,
8 individual stacks, 138 g/s NO_x;
Meteorology: Zejtun observations
Resolution: 100m, 8760 hourly runs.

Annual average maximum: 13.00 µg/m3
Hourly maximum: 146.05 µg/m3

Compliance: (simulated NO_x vs NO_2 standards)

annual standard: in compliance
hourly standard: in compliance

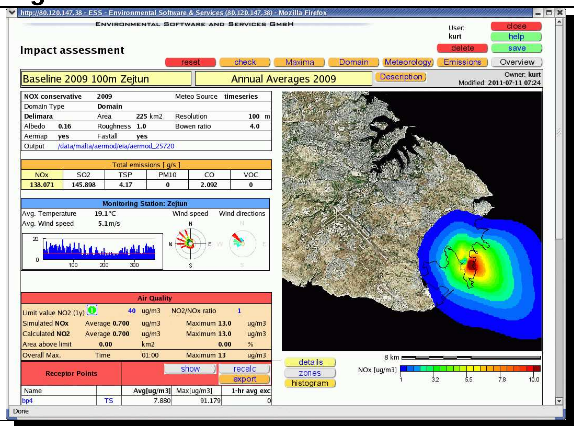


Figure 36. Baseline 2009

Baseline 2010: Delimara 305 MW,
8 individual stacks 138 g/3 NO_x;
Meteorology: Zejtun observations
Resolution: 100m, 8760 hourly runs.

Annual average maximum: 13.00 µg/m3
Hourly maximum: 145.62 µg/m3

Compliance: (simulated NO_x vs NO_2 standards)

annual standard: in compliance
hourly standard: in compliance

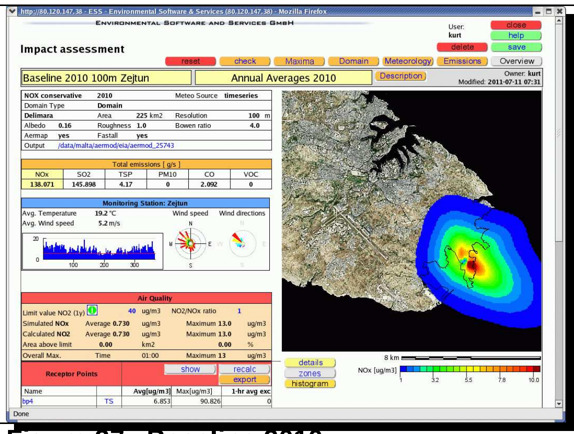


Figure 37. Baseline 2010

Please note that the color coding for these examples has been set to show concentrations starting from 1.0 µg/m^3 (blue) to 10.0 µg/m^3 (red); values below 1.0 are transparent, value above 10.0 are shown in dark red. These color definitions can be changed if required differently.

Table 19 summarizes the six baseline runs (tier 1 interpretation, comparing simulated NO_x against NO_2 standards). All six meteorological data sets show that predicted concentrations are in compliance, with the notable exception on ONE HOUR in 2009 in the immediate vicinity of the 150 m stack during a high-wind event that leads to an obvious anomaly in the Monin-Obukhov length (turbulence estimator) in the AERMET meteorological pre-processor AERMOD input file at the hour in question (11:00) which suggests a model artifact as the most likely explanation of this singular hourly exceedance value.

Table 19. Simulated maxima between 2008 and 2010. The non compliant hour in 2009 is likely to be a model artefact.

Simulation Year	AERMET from MM5-FNL		Zejtun observation time series	
	annual max	hourly max	annual max	hourly max
2008	1.40	120.53	13.90	145.98
2009	4.47	238.97	13.00	146.05
2010	3.84	131.70	13.00	145.62

NOTA BENE: the second highest value in 2009 is 149.54, the standard allows 18 violations/year.

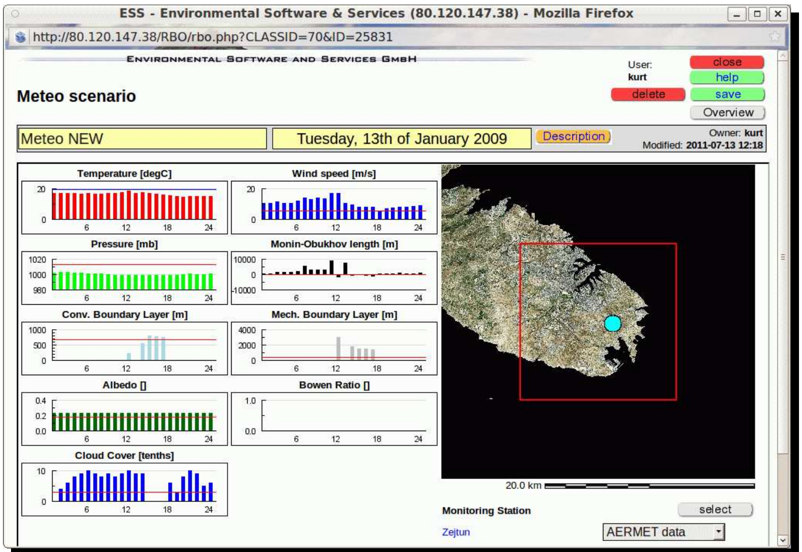


Figure 38. 24 hour meteo data for January 13, 2009 (AERMET, derived for Zejtun monitoring location)

To compare the tier 1 approach (NO_x conservative compared to NO_2 standards) the scenario for 2010 was also run with the AERMOD/OLM method (Table 20), with a ozone background concentration of 75µ/m3 (derived from the Zejtun monitoring data for the period 20080101 to 2009 05 31) no difference found, the OLM method generates the same maxima, which would imply 100% NO_2 in the simulated NO_x values.

Table 20. 2010 scenario re-run using AERMOD/OLM. No difference in maxima identified.

Simulation Year	AERMOD (NO_x)		AERMOD/OLM (NO_2)	
	annual max	hourly max	annual max	hourly max
2010	3.84	131.7	3.84	131.7

7.2.2 Baseline scenarios: NO_x, with regional emissions/background

The same six baseline runs described above (5.1.3) were also run with a combination of the DPS emission and local/regional emission for other sources, (see also Section 4.2) including:

- Marsa Power Station
- Thermal Waste Treatment facility
- road network within the 15 km model domain
- Malta international airport
- Valletta harbor and Malta Freeport
- Several smaller sources including:
  - Oil Tanking Malta
  - San Lucjan Oil Company
  - 31st March 1979 Fuel storage (ENEMALTA)
  - Wied Dalam Depot
  - Crusher operations

Summary of NO_x scenarios:

For selected days where the annual simulations (of all point and area sources) have indicated extreme hourly values, detailed high resolution model runs (including 10 m resolution for the traffic sources) 24 hour runs were conducted (see the tabular summary below)

Table 21. Maximum hourly NO_x concentrations w/o background, AERMOD 24 hour runs (including traffic at 10 m resolution) for the six daily scenarios with high hourly maxima.

Date of 24 hours scenario run	maximum hourly concentration µg/m^3	
	DPS + BG	DPS only
2008 11 28	153.30	120.53
2008 09 11	303.80	118.63
2009 01 13	228.90	238.97
2009 03 04	160.80	149.54
2010 07 22	548.00	131.70
2010 06 26	314.30	127.25

These six 24 hour NO_x scenarios with all sources considered yield a higher number of violations of the hourly NO_2 standard compared to simulated NO_x. Also, in most cases these violations are singular, related to extremely low mixing height (in combination with elevation correction using AERMAP pre-processor), or are all concentrated on a single day and several adjacent grid points.

Taking the case of 22-07-2010 and its extreme hourly maximum of 548 (Table 21), the analysis shows that the violations are concentrated around Valletta and the Marsa TPS (Figure 39), and that population exposure is minimal within the 15 km model domain (1.9 km2, 851 persons) with none in the 6km impact zone around DPS.

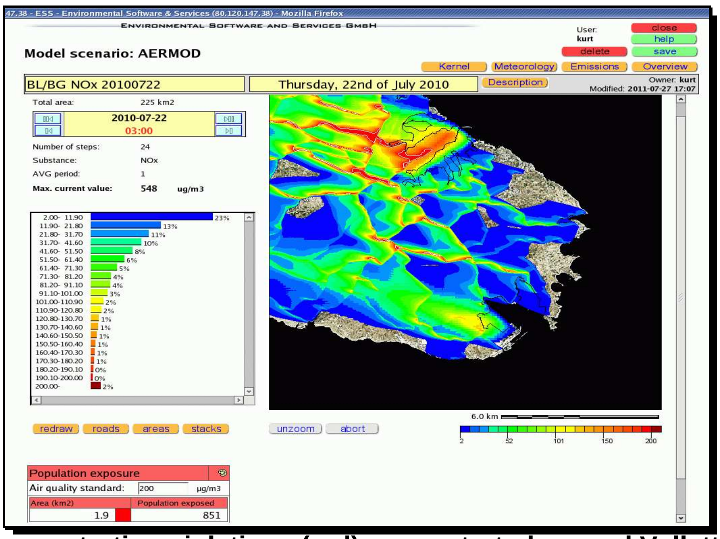


Figure 39. Hourly concentration violations (red) concentrated around Valletta and the Marsa TPS

CAMx, nested grid NO_x/NO_2 simulations

A parallel estimate for NO_x/NO_2 ambient values is derived from continuous model runs (using NCEP-GFS meteorology and dynamic downscaling with MM5) of CAMx. Model domain consist of three nested levels:

- a 2,400 km European (EMEP) domain with EMEP (2009) emission data on a 60 km grid;
- a 240 km domain around Malta that includes the Southern part of Sicily, and uses the results from the European EMEP domain as dynamic boundary conditions (two-way coupling)
- a 40 km domain the include the islands tightly.

Table 22. Simulated average and maximum ambient air quality parameter values.

pollutant (µg/m^3)	average	maximum
NO_x (CAMx)	54.2	445.4
NO_2 (CAMx)	45.4	201.0
NO_2 (monitored)	35.1	332.6
PM_{10} (CAMx)	20.4	439.4
PM_{10} (monitored)	26.0	1,581.2
NOTA BENE: the calculated vs observed average values are well within the +/-50% quality requirement defined in Directive 2008/50/EC.		

From these model runs, the estimated values for NO_x and NO_2 are extracted for the location of the Zejtun monitoring station for a total of 792 hours of continuous simulation (June 24, 2011 to July 26 (forecast) 2011) from all three resolutions (500m, 1,000m, 3,000 m); the innermost domain at 500m is summarized in Figure 40 and compared with actual observation data at Zejtun (2,842 observations). The extreme value of 1,581 µg/m^3 (Table 22) is due to a singular event in January 2009. Both measurements and simulation results show high hourly variability, but a clear daily pattern of the ambient concentration, that correlates with wind direction (sea breeze) and wind speed daily variations.

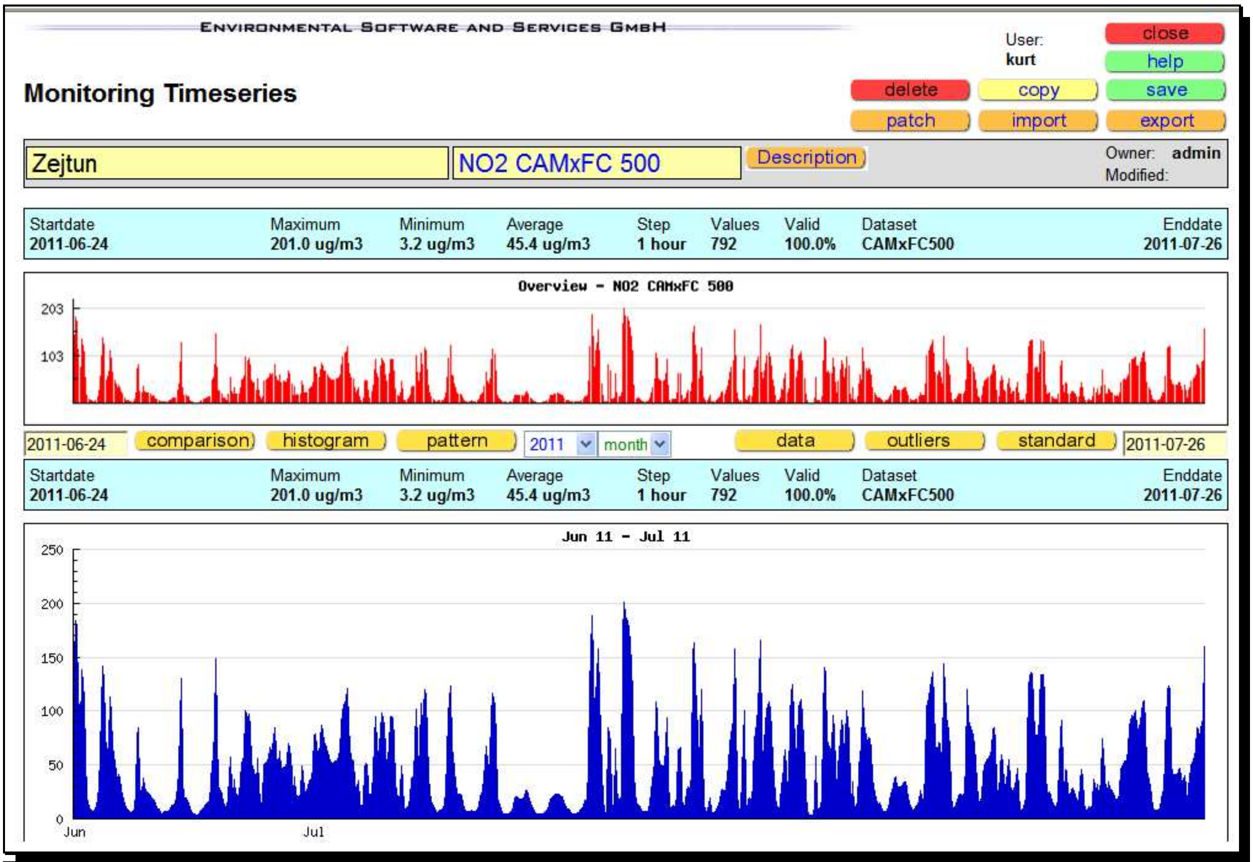


Figure 40. Time series of hourly NO_2 values for the location Zejtun monitoring stations, extracted from the 3D nested grid Eulerian model CAMx with full photochemistry.

7.2.3 Baseline scenarios: PM_{10}

Estimated PM emission values vary considerably. The original IPPC permit (IPPC Part B Delimara Power Station) refers to total plant emissions (baseline scenario) of 390.936 tons/year, or **12.4 g/s** PM_{10} (estimated; no fly ash collection system is in place). A second estimate for baseline PM emissions is derived from the document on planned variations (Enemalta, Application for variation to DPS IPPC Permit: New Plant) which refers to incremental emissions from the so-called “new plant” of 360 tons/year; this would amount to about 25 g/s. Under the worst case assumption that no bag filters are in operation, this should represent roughly 50% of the baseline scenario. The second estimate for baseline PM emissions is therefore **50 g/s** $\mathbf{PM_{10}}$. The specific PM_{10} concentration (IPPC permit variation No6.) of **136 mg/m^3** of flue gas, when multiplied with the actual measured flue gas volumes at DPS 1A and 1B (combined into the common 150 m stack) yield **16 g/s**; D1 (weighted by MW thermal) contributes about 40% of the total (baseline) plant emissions. Extrapolating this to 100% results in a third PM_{10} emission estimate of **40 g/s** $\mathbf{PM_{10}}$.

In line with basic impact assessment methodology, the highest (worst case) estimate, of **50 g/s** PM is used for the baseline emissions scenario (and a total of 75 g/s for the extension scenario). To account for different release heights, this total is allocated to the different stack emission heights, flue gas temperatures and speeds, in proportion to the NO_x emissions, as shown in Table 24.

Table 24. NO_x and PM_{10} emissions estimates for the DPS Baseline Scenario

	NO_x g/s	%	PM_{10} g/s
D1a	35.1	0.254	12.71
D1b	29.6	0.214	10.72
D2	0.5	0.004	0.18
D3	1.9	0.014	0.69
D4a	6.7	0.049	2.43
D4b	23.5	0.170	8.51
D5a	22.6	0.164	8.18
D5b	18.2	0.132	6.59
	138.1	1.000	50.000

With these emission values, screening level AERMOD scenarios were run for the years 2008, 2009, and 2010 with the results summarized below. While no specific emission data for $PM_{2.5}$ are available, $PM_{2.5}$ is a fraction (subset) of PM_{10} and values for $PM_{2.5}$ can only be below values for PM_{10}. Table 25 shows average and maximum PM_{10} values calculated for (within) the 6 km radius impact zone. All calculated values are well below the applicable air quality standards.

Table 23. Annual average and daily and hourly maximum values for PM_{10} within the 6km radium impact zone. Values highlighted in green indicate compliance with applicable air quality standards.

Baseline YEAR PM_{10} scenarios	annual AVG	daily MAX	hourly MAX at receptor stations (PM_{10} values in µg/m3)	
2008	0.50	18.43	26.52	Ghar Dalam cave
2009	1.59	15.92	27.88	Ghar Dalam Cave
2010	1.36	14.68	18.12	Cottonera Sports Complex
AVERAGE	1.15	34.20		

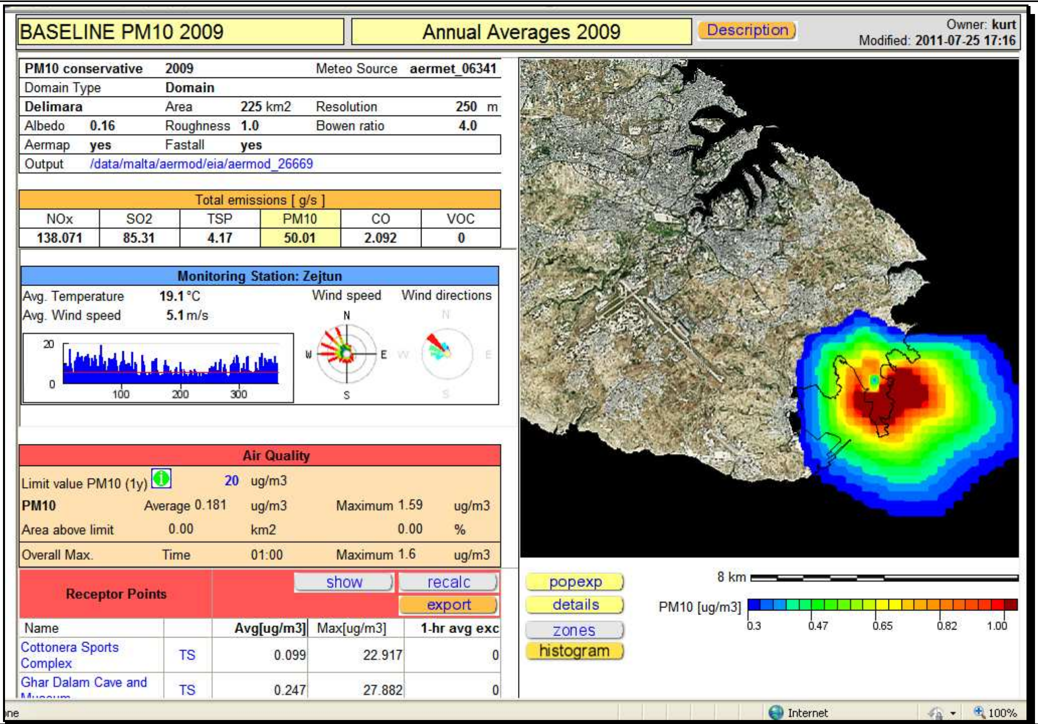


Figure 41. PM_{10}, baseline 2009: annual average, color scale to 1µg/m³ (2.5 % of standard)

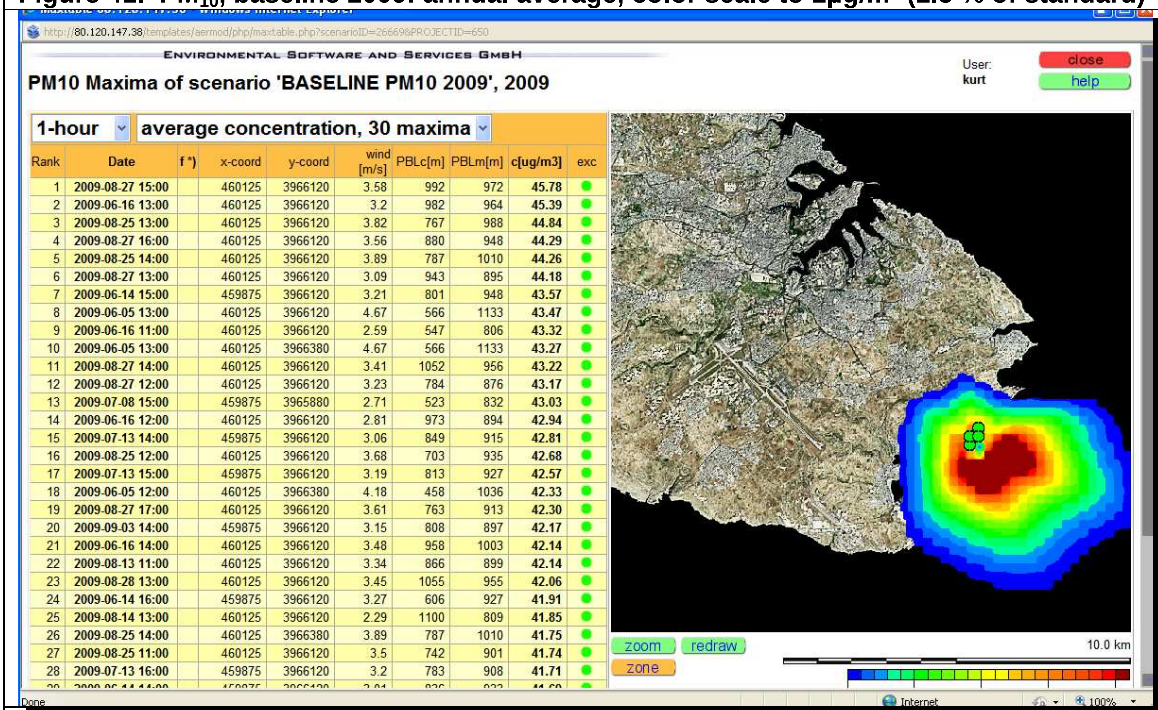


Figure 42. PM_{10}, baseline 2009: location of hourly maxima (first 30 events)

7.2.4 PM_{10}: Baseline with background

The PM_{10} emissions from the DPS are combined with the PM_{10} emissions from the Marsa TPS (estimated), and emissions from the other point and area sources in the 15 km model domain (total of 22 sources, see section 4.2) which add approximately 60 g/s PM_{10} to the DPS plant's basic emissions of 50 g/s.

Simulation results that assume the "worst case" meteorology for 2008 indicate:

- annual average concentration (maximum): 12.1 µg/m^3
  in compliance
- daily maxima: 61.29 µg/m^3
  exceeding the 50 µg/m^3 daily standard four times in two locations in the overall domain, one exceedance within in the 6 km radius.
  in compliance with Directive 50/2008/EC, < 35 exceedances/year

Violations are predicted at 2-4 locations (on the 100 m receptor grid and indicated in the figures below for a total of 4 days during 2009, and thus well within the limit of 35 allowable exceedances of the PM_{10} daily limit value. Results for 2009 and 2010 are consistent.

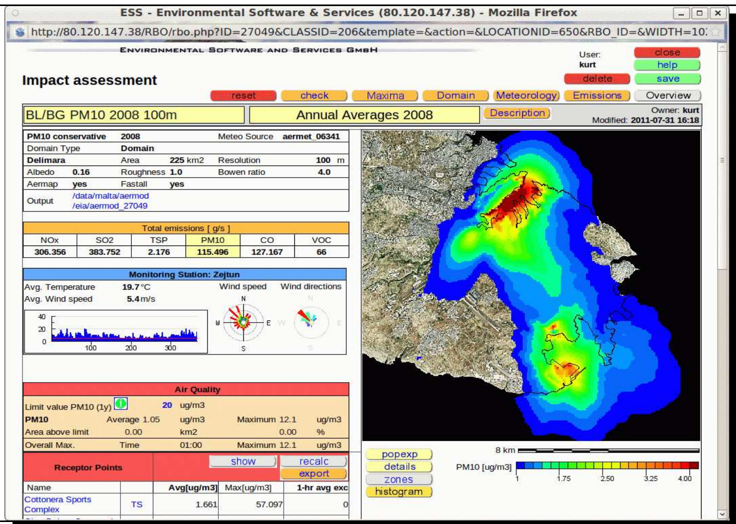


Figure 43. PM_{10}, 2010, DPS baseline plus background; colour coding exaggerated from 1-4 µg/m3 to highlight distribution

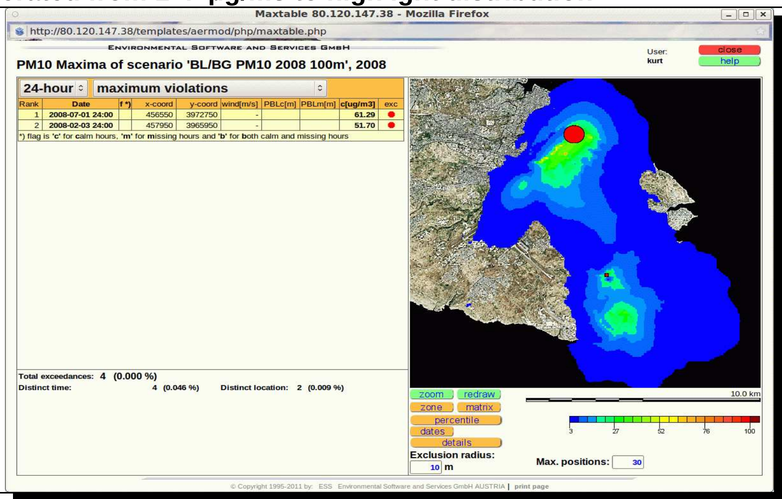


Figure 44. PM_{10}, 2010, locations of the exceedances

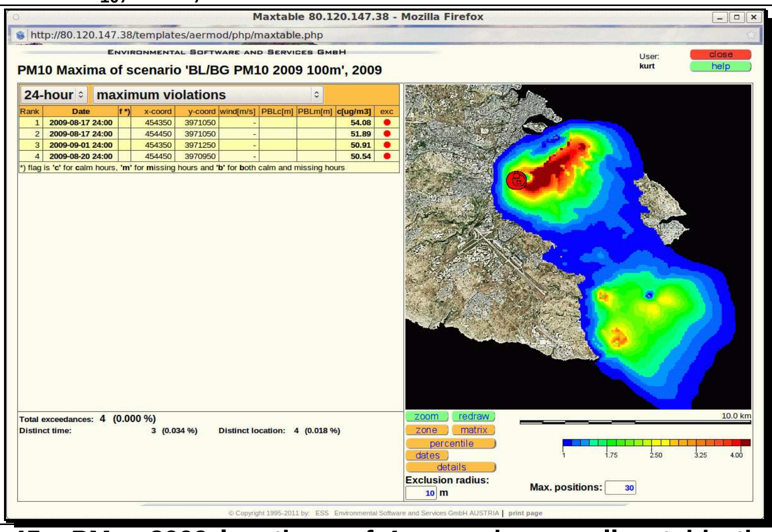


Figure 45. PM_{10}, 2009 locations of 4 exceedances all outside the 6 km radius

7.2.5 Baseline scenarios: B[a]P, heavy metals

Stack emission data (concentrations) for PAHs (Table 26) were all below detection limits, so that no inputs for dispersion modeling could be derived. Literature values for a range of large industrial boilers (energy generation) for B[a]P suggest emission values between 1.0 and 0.05 mg/ton of (refined) oil; emission factor for heavy oil are on average an order of magnitude higher than for diesel fired boilers.

Table 24. Poly Aromatic Hydrocarbons

PAHs (all ND, < 0.1 ng)
Benzo(a)pyrene
Naphthalene
Anthracene
Phenantrene
Fluoranthene
Benzo(a)anthracene
Chrysene
Benzho(ghi)perylene
Benzo(k)fluoranthene
Indeno-pyrene

Benzo (a) Pyrene CAS 50-32-8
Source: EPA/AP-42, WEBFIRE

Table 257. B[a]P Emission Factor values and units for various sources.

Source	**Control**	**EF value**	**Unit**
External Combustion Boilers > Electric Generation > Bituminous/Subbituminous Coal	uncontrolled	97.2	mg per ton Coal Burned
External Combustion Boilers > Electric Generation, Industrial > Bituminous/Subbituminous Coal, Lignite	miscellaneous	0.000000038	Lb per Tons Bituminous Coal Burned
External Combustion Boilers > Electric Generation > Distillate Oil	uncontrolled	0.00000134	Lb per 1000 Gallons
External Combustion Boilers > Electric Generation, Industrial > Natural Gas	uncontrolled	0.0000012	Lb per Million Cubic Feet
External Combustion Boilers > Electric Generation, Industrial > Wood/Bark Waste	uncontrolled	0.0000026	Lb per Million Btus Heat Input
External Combustion Boilers > Industrial > Wood/Bark Waste	MULTIPLE CYCLONE W/O FLY ASH REINJECTION	< 7.500E-9	Lb per Million Btus Heat Input
External Combustion Boilers > Industrial > Wood/Bark Waste	miscellaneous	6.750E-8	Lb per Tons Bark Burned
External Combustion Boilers > Industrial > Process Gas	uncontrolled	0.00000102	Lb per Million Btus Heat Input
External Combustion Boilers >	uncontrolled	100	mg per ton Waste

Industrial > Liquid Waste			Burned

Table 28 specifies the heavy metal concentrations and mass flux were reported for the main 150m DPS stack and used for baseline simulation:

Table 26. Heavy metal concentrations and flow measurements used for DPS baseline simulations. Source: Enemalta.

Boiler/stack	DPS 1A		DPS 1B		TOTAL
metal species	mg/Nm3	mg/h	mg/Nm3	mg/h	mg/s
Cadmium, Thallium	0.003	731.784	0.003	534.453	0.352
Arsenic	0.001	243.928	0.001	178.151	0.117
Chromium	0.032	7805.696	0.046	8194.946	
Cobalt	0.002	487.856	0.003	534.453	
Copper	0.003	731.784	0.006	1068.906	
Manganese	0.003	731.784	0.004	712.604	
Nickel	0.059	14391.752	0.084	14964.684	8.155
Lead	0.05	1219.640	0.009	1603.359	3.833
Antimony	0.004	975.712	0.006	1068.906	
Vanadium	0.032	7805.696	0.046	8194.946	
Metals (total)	0.19	46346.320	0.21	37411.710	

The screening scenarios related to metals were also run with the meteorology (AERMET from NCEP-FNL re-analysis runs) and a 250 m receptor grid resolution, for the years 2008, 2009, and 2010. Based on the stack measurements, the following scenarios were simulated based on the measured emissions from DPS joint 150 m stack, boilers D1A, D1B, corrected to the total estimated DSP emissions (* 2.5)

Table 279. Simulated annual average concentration maxima of metals and BaP

Pollutant species	emissions mg/s	annual AQ standard	Annual average maximum [1)] ng*/ m^3		
			2008	2009	2010
Cadmium/Thallium	0.88	5 ng/m^3	0.007	0.019	0.016
Arsenic	0.29	6 ng/m^3	0.002	0.006	0.005
Nickel	20.39	20 ng/m^3	0.170	0.436	0.372
Lead	9.68	500 µg/m^3	0.077	0.209	0.176
Benzo[a]Pyrene [2)]	0.03	1 ng/m^3	0.00025	0.000605	0.000530

[1)] maximum on a 100m grid in the 6 km radius circle around DPS for annual averages (average over 8,760 hourly steady-state solutions)
[2)] estimated emissions (worst case assumption = flue gas concentration at detection limit: 0.1 ng/m3)

The computed ambient concentrations based on the estimated emissions (based on DSP D1A and 1B stack monitoring data, scaled for DSP average emissions) are, even for the "worst case" of Nickel, below the applicable annual standard by a factor of 50, and by a factor of 400 for B[a]P. This clearly indicates that even with a (very conservatively assumed) fourfold increase due to other sources/background and a

50% increase in emissions (assuming the unlikely worst case of 0 efficiency of the bag filter for the new boilers/stacks) any violations of the standard can be safely excluded.

The observed metal concentrations (daily average values at Marsaxlokk and Birzebbugia during a 19 day observation period. However, comparing a small number of daily values with estimated annual averages is difficult. Using a 100 m receptor grid resolution, maxima for 24 hour averages for Ni for example, have been computed with 7.5 ng/m^3 (annual average 2009: 0.75), which corresponds reasonably well with observed values. (Nickel, average over 19 daily value: 4.6, maximum daily value: 29.0).

The locations of the expected maxima (computed for particulates) are all in the close vicinity of the release points due to the deposition of the ash/particles, downwind of the source, and partly over the sea (Figure 46).

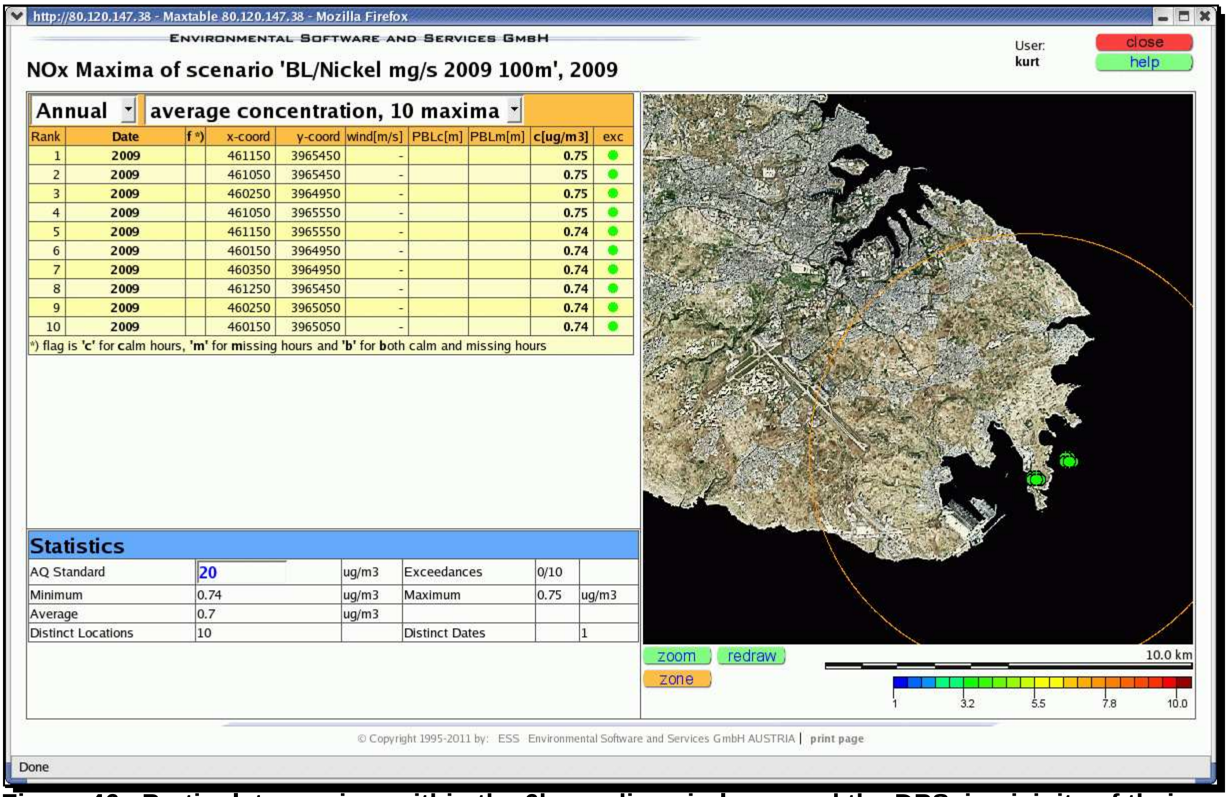


Figure 46. Particulate maxima within the 6km radius circle around the DPS, in vicinity of their release points.

The computed estimates, however, are well below the annual average standard for Nickel at 20 ng/m^3. Since the estimated emissions for Nickel are by far the highest, and the model is linear in emissions, all other metals are expected to be found at even lower annual average concentrations and thus in compliance with the air quality standards.

7.3 DPS extension scenarios

The extension of the DPS includes eight diesel engines, sharing four stacks (65 m height, 2.1 m diameter) in groups of two adding a capacity of 4 * 77 MW_{th} to the system, burning HFO and gasoil. SCR, $DeSO_x$, and bag filters are foreseen for emission reductions.

The IPPC permit application (variation) estimates total NO_x emissions of 1,064 tons/year of NO_x and 390 tons/year of particulates, both independent of fuel[5]. In line with basic impact assessment methodology, the worst case value available for particulate matter is used. This value reflects a situation in which bag filters are not in operation. Emissions for heavy metals and B[a]P are increased in proportion to capacity (+50%) due to the lack of any more specific data. The additional emissions for the four additional 65m stacks are therefore:

- 34 g/s NO_x (8.50 g/s per stack, 25% over the baseline)
- 25 g/s particulates (6.25 g/s per stack, 50% over the baseline)

The resulting annual average DPS emission estimates total emissions over the 12 emission points for the Extension scenario. These are summarized in Table 30. The background concentrations and underlying emissions are assumed to be constant for the purpose of the assessment and comparison of baseline and extension scenarios, even though increasing traffic generated emissions for all sectors (road, shipping, airport) could be assumed under future economic growth assumptions.

Table 30. Annual average emissions estimates for the DPS extension scenario

Pollutant	**emissions g/s**	
	baseline	extension
NO_x	138.1	**172.0**
PM_{10}	50.0	**75.0**
Pollutant	emissions mg/s	
	baseline	extension
Cadmium/Thallium	0.88	**1.32**
Arsenic	0.29	**0.44**
Nickel	20.39	**30.59**
Lead	9.68	**14.52**
Benzo[a]Pyrene	0.03	**0.05**

[5] **Note that on the other hand SO_2 emissions (assessment of which was not included in the TOR for the present study) on the other hand would vary from 789 tons/year to 452 tons/year for HFO and gasoil, respectively.**

7.3.1 Extension scenarios: NO_x, DPS emissions only

Extension scenario, meteo 2008: DPS 450 MW, 12 individual stacks, 172 g/s NO_x;
Meteorology: MM5/AERMET,
Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 2.42 µg/m3
Hourly maximum: 138.94 µg/m3

Compliance: (simulated NO_x vs NO_2 standards)

annual standard : in compliance
hourly standard : in compliance

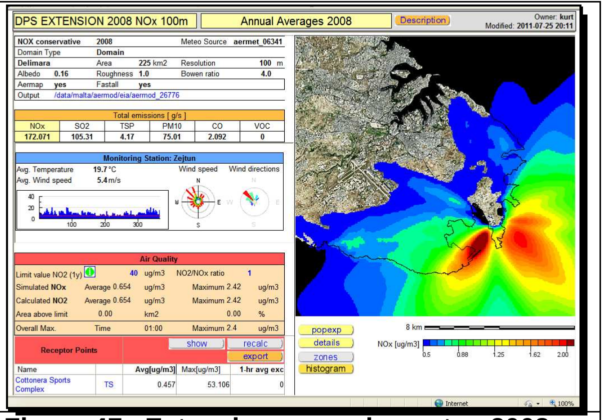


Figure 47. Extension scenario, meteo 2008

Extension scenario meteo 2009: DPS 450 MW, 8 individual stacks, 172 g/s NO_x;
Meteorology: MM5/AERMET,
Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 6.89 µg/m3
Hourly maximum: 238.97 µg/m3
(two singular events !)

Compliance: (simulated NO_x vs NO_2 standards)

annual standard : in compliance
hourly standard : two violations (less than 35)

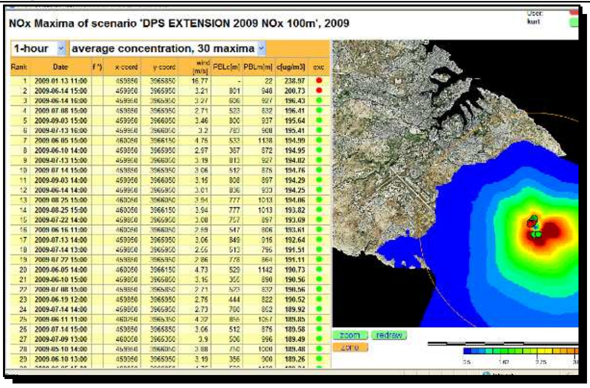


Figure 48. Extension scenario meteo 2009

Extension scenario, meteo 2010: DPS 450 MW, 8 individual stacks, 172 g/s NO_x;
Meteorology: MM5/AERMET,
Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 5.78 µg/m3
Hourly maximum: 203.16 µg/m3
(three events !)

Compliance: (simulated NO_x vs NO_2 standards)

annual standard : in compliance
hourly standard : three violations (less than 35)

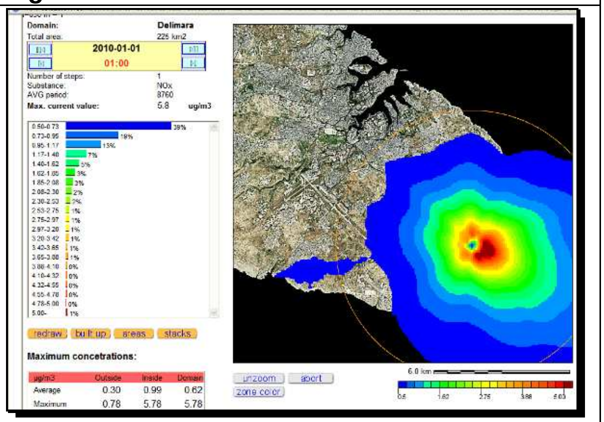


Figure 49. Extension scenario, meteo 2010:

7.3.2 Extension scenarios: NO_x, with regional emissions/background

To account for the high-resolution (10 m) of the line source (traffic network) representation, the combined simulations of point, area and line sources is restricted to those days (24 hourly runs) where the annual runs for the point sources (extension scenarios) have indicate maxima of concentrations. The corresponding dates are listed in the table to the right.

Table 31. Hourly maximum NOx concentrations for the six simulations at high resolution.

NO_x simulation date extension scenarios	hourly max.	
	DPS only	DPS + BG
2008 05 01	138.92	**232.5**
2008 09 03	133.50	**316.9**
2009 01 13	238.97	**228.9**
2009 06 14	196.73	**355.3**
2010 06 08	203.16	**426.1**
2010 07 22	202.38	**548.0**

Nota bene: the 24 hour scenarios incl. traffic at 10 m resolution are run without the AERMAP terrain corrections, which leads to lower values, by a few %, when compared to the basic annual runs. Where elevated receptor points and extremely low mixing height coincide, the value for DPS only can therefore slightly exceed the value of DPS+BG.

The results for the six worst case scenarios (dates) are shown in Figures 50-55.

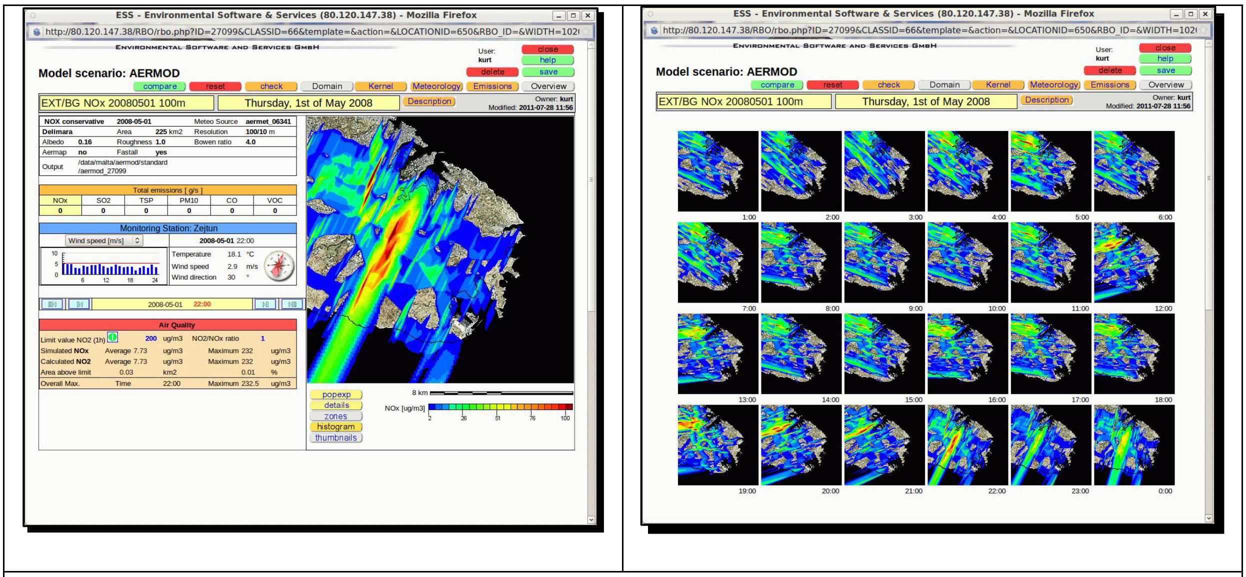
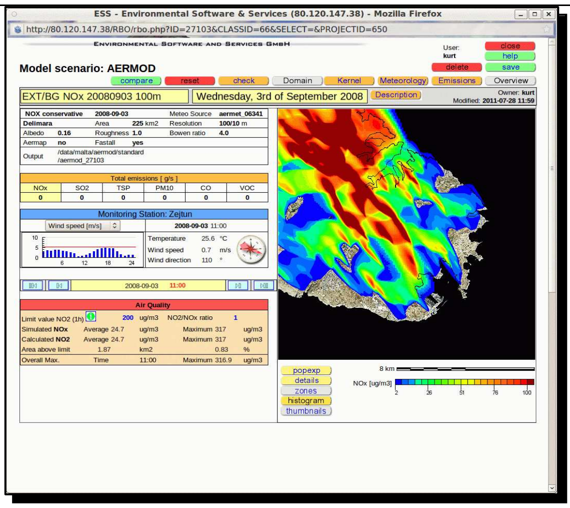


Figure 50. NO_x, DPS with all background sources, hourly max. (left) and 24 hours of 01-05-2008



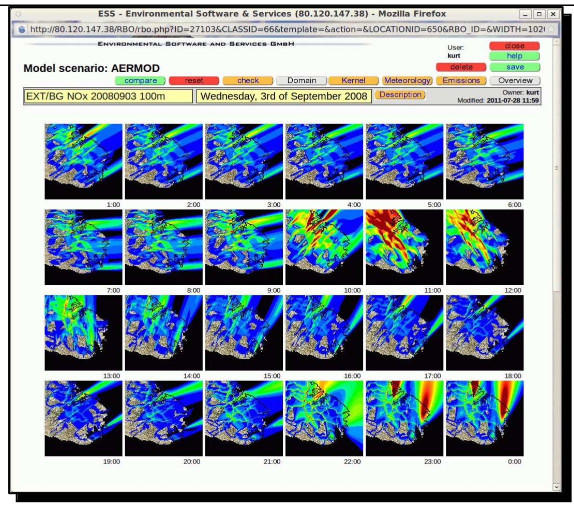
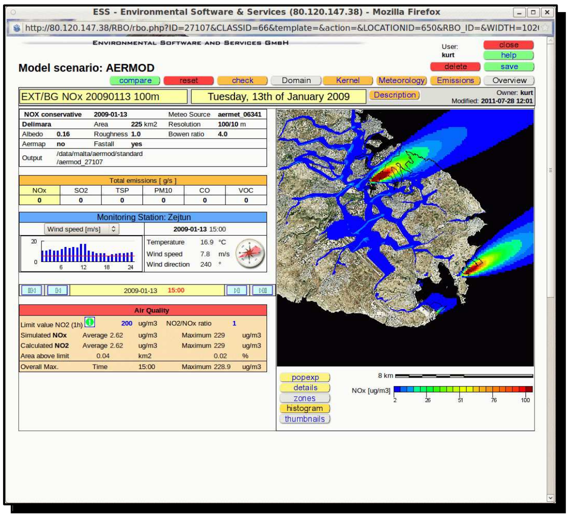


Figure 51. NO_x, DPS with all background sources, hourly max. (left) and 24 hours of 03/09/2008



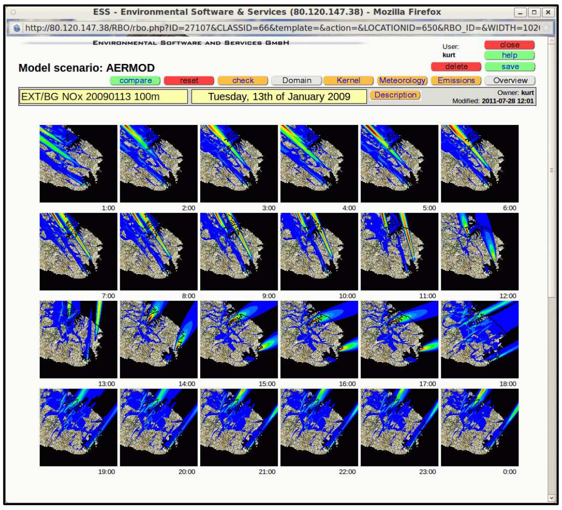
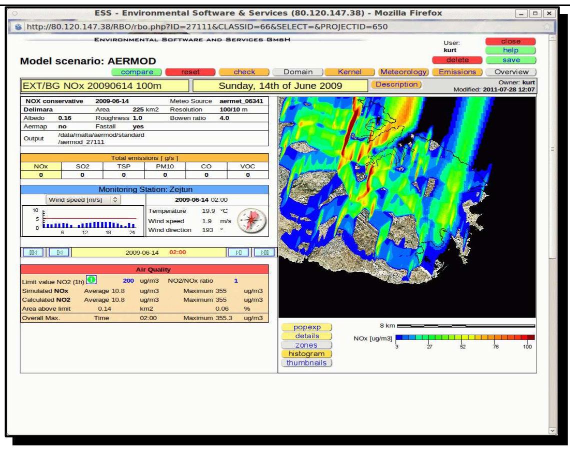


Figure 52. NO_x, DPS with all background sources, hourly max. (left) and 24 hours of 13/01/2009



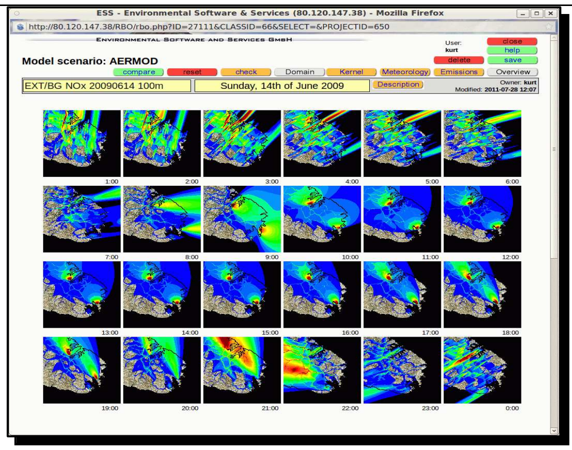


Figure 53. NO_x, DPS with all background sources, hourly max. (left) and 24 hours of 14/06/2009

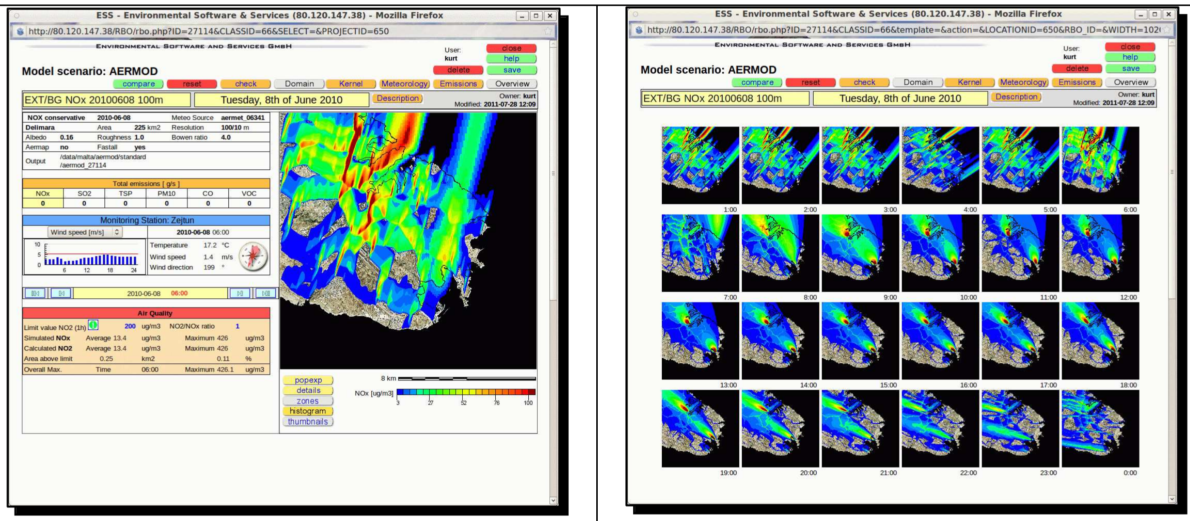


Figure 54. NO_x, DPS with all background sources, hourly max. (left) and 24 hours of 08/06/2010

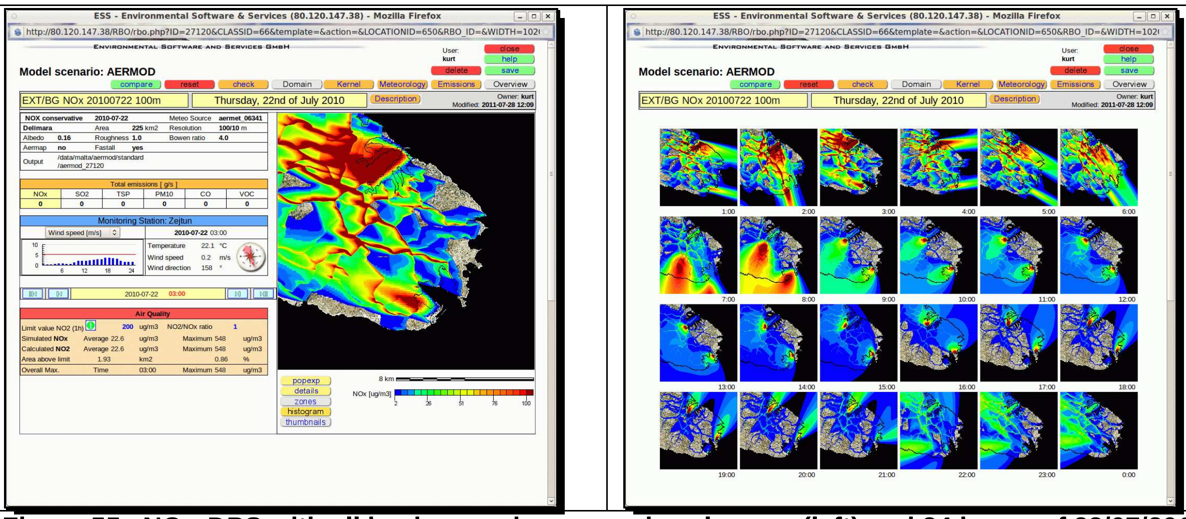


Figure 55. NO_x, DPS with all background sources, hourly max. (left) and 24 hours of 22/07/2010

Annual runs:

To determine the annual average concentrations for the combined scenarios (based on 8760 hourly solutions), the 12 DPS (extension scenarios) have been combined with all other point and area sources, that together cover NO_x emissions of ~330 g/s (excluding traffic), or about 91 % of the total (~360g/s NO_x in the 15 km domain, from a total of 862 distinct emission sources, including traffic with 836 road segments).

The annual runs (DPS + BG, point and area sources) are summarized in Table 32.

Table 32. Annual and hourly simulated maxima for the Delimara Power Station and background emission sources.

year	annual. max.	hourly max.	hours	%	locations	%
2008	30.8	920.45	382	4.36	2,997	13.32
2009	20.2	384.47	2,155	24.60	2,183	9.70
2010	21.5	558.53	2,149	24.32	2,266	10.07

Hourly violation (maxima) and their locations are shown below:

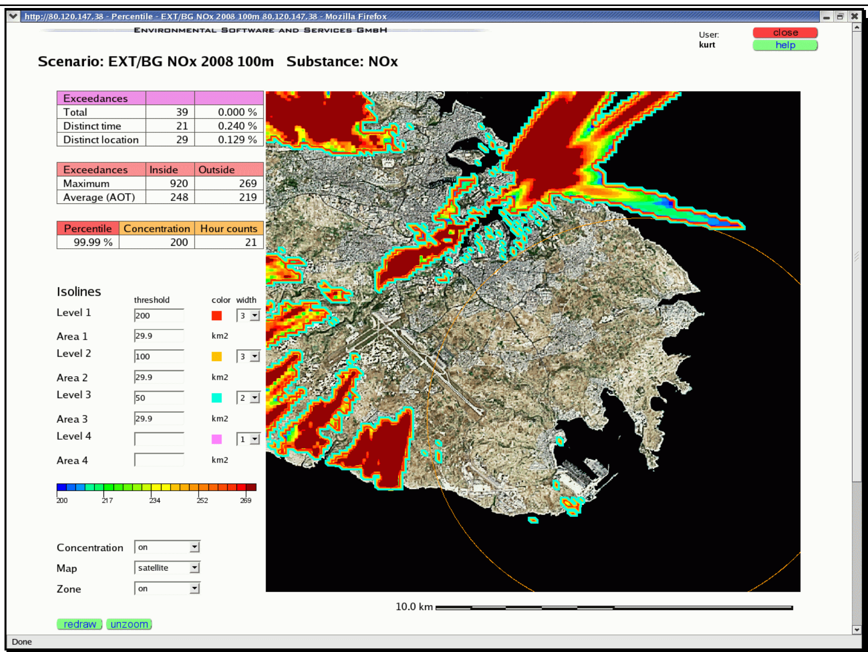
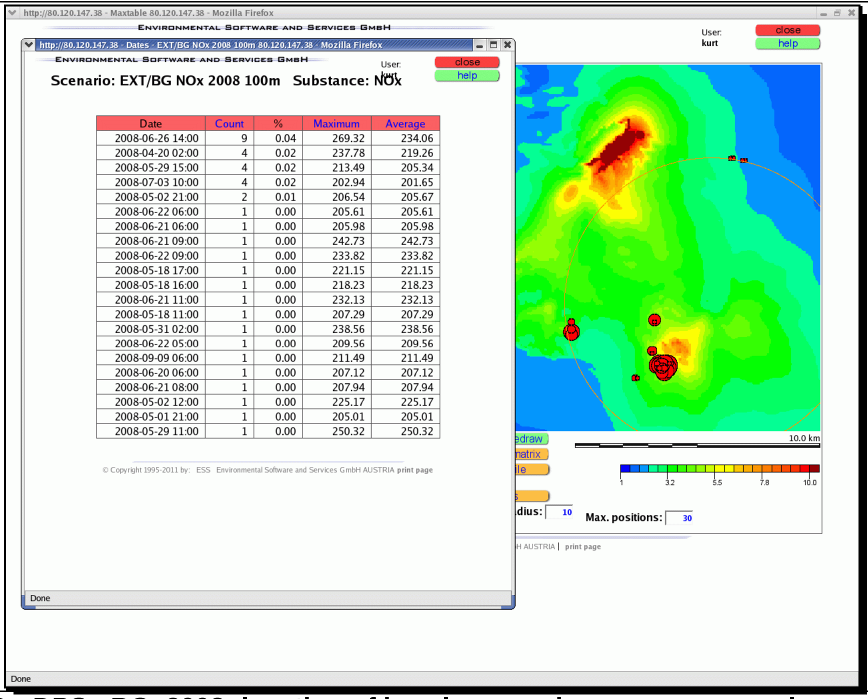


Figure 56. NO_x, DPS +BG, area of exceedances, 2008 (39 exceedances violates Directive 50/2008/EC)



Date	Count	%	Maximum	Average
2008-06-26 14:00	9	0.04	269.32	234.06
2008-04-20 02:00	4	0.02	237.78	219.26
2008-05-29 15:00	4	0.02	213.49	205.34
2008-07-03 10:00	4	0.02	202.94	201.65
2008-05-02 21:00	2	0.01	206.54	205.67
2008-06-22 06:00	1	0.00	205.61	205.61
2008-06-21 06:00	1	0.00	205.98	205.98
2008-06-21 09:00	1	0.00	242.73	242.73
2008-06-22 09:00	1	0.00	233.82	233.82
2008-05-18 17:00	1	0.00	221.15	221.15
2008-05-18 16:00	1	0.00	218.23	218.23
2008-06-21 11:00	1	0.00	232.13	232.13
2008-05-18 11:00	1	0.00	207.29	207.29
2008-05-31 02:00	1	0.00	238.56	238.56
2008-06-22 05:00	1	0.00	209.56	209.56
2008-09-09 06:00	1	0.00	211.49	211.49
2008-06-20 06:00	1	0.00	207.12	207.12
2008-06-21 08:00	1	0.00	207.94	207.94
2008-05-02 12:00	1	0.00	225.17	225.17
2008-05-01 21:00	1	0.00	205.01	205.01
2008-05-29 11:00	1	0.00	250.32	250.32

Figure 57. NO_x, DPS +BG, 2008; location of hourly exceedances over annual average conc. table of dates/time of exceedance with max and average hourly values for the 6 km primary impact zone

7.3.3 Extension scenarios: PM_{10}

DPS emissions only (12 stacks)

Extension scenario, meteo 2008: DPS 450 MW, 12 individual stacks, 75 g/s PM_{10}; Meteorology: MM5/AERMET, Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 1.27 µg/m3
Daily average maximum: 35.65 µg/m3

annual standard : in compliance
24 hour standard : in compliance

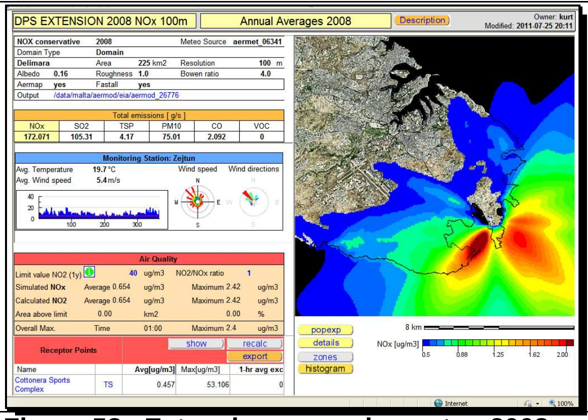


Figure 58. Extension scenario, meteo 2008

Extension scenario, meteo 2009: DPS 450 MW, 12 individual stacks, 75 g/s PM_{10}; Meteorology: MM5/AERMET, Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 3.40 µg/m3
Daily average maximum: 40.40 µg/m3

annual standard: in compliance
24 hour standard : in compliance

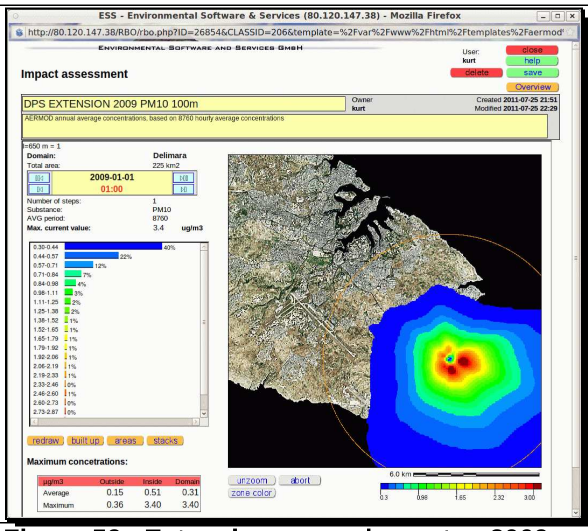


Figure 59. Extension scenario, meteo 2009

Extension scenario, meteo 2010: DPS 450 MW, 12 individual stacks, 75 g/s PM_{10}; Meteorology: MM5/AERMET, Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 2.82 µg/m3
Daily average maximum: 38.49 µg/m3

annual standard: in compliance
24 hour standard : in compliance

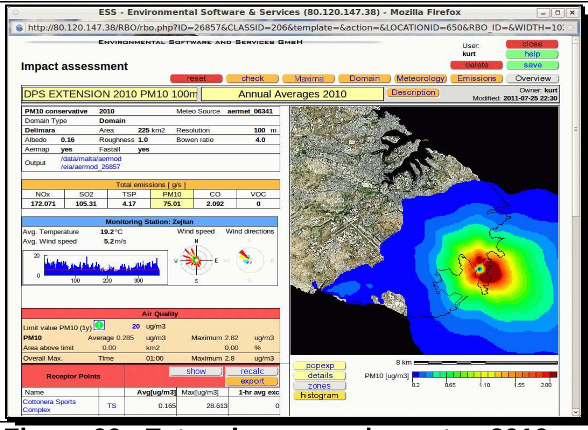


Figure 60. Extension scenario, meteo 2010

DPS emissions plus background (point and area sources, 100 m receptor grid)

Extension scenario, meteo 2008: DPS 450 MW, 12 individual stacks, background 146 g/s PM_{10}; Meteorology: MM5/AERMET, Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 12.20 µg/m3
Daily average maximum: 61.29 µg/m3

annual standard : in compliance
24 hour standard : 4 exceedances, in compliance

1 (> 35) events in the 6km radius zone

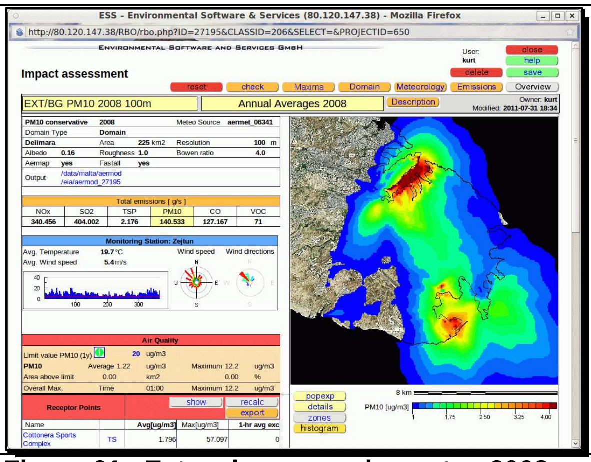


Figure 61. Extension scenario, meteo 2008

Extension scenario, meteo 2009: DPS 450 MW, 12 individual stacks, background, 146 g/s PM_{10}; Meteorology: MM5/AERMET, Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 8.03 µg/m3
Daily average maximum: 54.08 µg/m3

annual standard: in compliance
24 hour standard : 6 exceedances, in compliance

0 events in the 6km radius zone

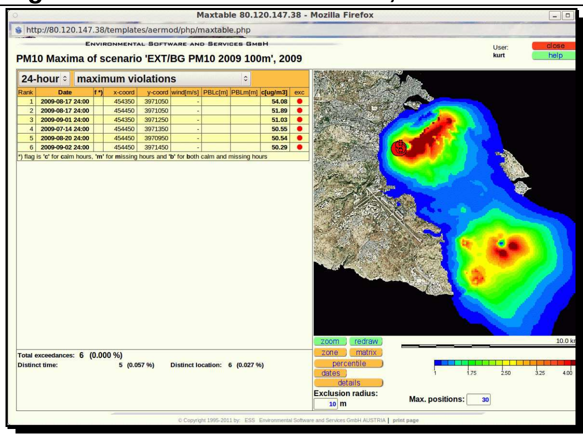


Figure 62. Extension scenario, meteo 2009

Extension scenario, meteo 2010: DPS 450 MW, 12 individual stacks, background 146 g/s PM_{10}; Meteorology: MM5/AERMET, Grid resolution: 100 m, 8760 hourly runs.

Annual average maximum: 8.54 µg/m3
Daily average maximum: 54.85 µg/m3

annual standard: in compliance
24 hour standard : 6 exceedances, in compliance

0 events in the 6km radius zone

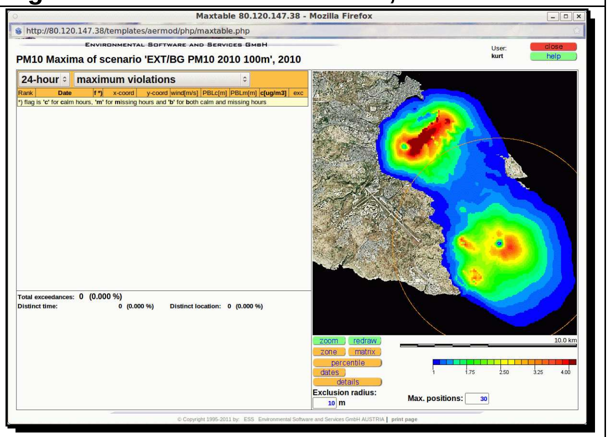


Figure 63. Extension scenario, meteo 2010

7.3.4 Extension scenarios: B[a]P, heavy metals

The expected increase in the emission of metals and B[a]P of 50% (parallel to the PM_{10} emissions, but depending on the operational efficiency of the bag filters on the new diesel engines/stacks) will not lead to any violations of the annual standards, as the values for the baseline scenarios were found to be one or more orders of magnitude below the annual average standards or target values.

7.4 Decommissioning the Marsa Power Station

The Marsa Power Station MPS is the single most important contributor to the background emissions (143 g/s out of a total of 168 g/s) and thus a major contributor to ambient concentrations in the larger area around the plant. MPS (2009 meteorology) alone contributes 11,795 (0.006%) exceedances of NO2 hourly standards, at 2,062 hours during a year (23%), and at 1,610 ha (7 % of the model domain), even though its effect within the 6 km radius around DPS is rather limited: 61 exceedances inside the 6km circle around DPS, at 23 hours).26%), and a total of 40 ha (0.18%).

To estimate the effect of a possible decommissioning of Marsa, once the DPS extension is in operation, the scenario “Combined emissions (DPS extension plus background, but without MPS” has been run over the three years 2008, 2009, 2010. The expected impacts in the 15km domain, on the relative improvement of air quality indicators (based on 2008 meteorology) for the DPS extension scenario together with a decommissioning of MPS, are summarised as follows:

- 62% reduction of the total number of exceedances
- 75% reduction of the distinct times (hours) of exceedances
- 48% reduction of the area of exceedances

while the corresponding reduction of air pollution indices for the 6 km circle around DPS are 10%, 5%, and 15%, despite the larger distance from the MPS location and thus a reduced impact from MPS.

Please note that there is no reduction of the hourly maximum concentration expected, as under the current set of assumptions this is caused by the Valletta harbour (area source with a low emission level of 15 m). Also, the remaining exceedances are due to the Valletta harbour, and at least for the maxima predicted, restricted to the immediate vicinity and extreme weather conditions (inversion: very low mixing height and low wind speeds). This effect of low wind speed (around and below 1 m/s) is also evident from the dynamic Eulerian model CAMx, e.g., for the early morning hours of 2011 08 21.

Table 33. Average and hourly maxima, and number of exceedances, times and locations within the 15km and 6km areas, for 2008 DPS extension simulations with and without MPS emissions. The results are normalised to see the absolute and relative change as a result of the decommissioning of the MPS.

Year	Scope	AVG	HMAX	Exceedances	%	Times	%	Locations	%
Scenario: DPS extension, all background with MPS									
2008	15km	30.8	920.45	10,316	0.005	382	4.36	2,997	13.32
2008	6km	8.37	269.32	30	0.009	21	0.24	29	0.13
Scenario: DPS extension, all background without MPS									
2008	15km	29.2	920.45	3,931	0.002	97	1.11	1,534	6.82
2008	6km	7.57	269.32	25	0.000	20	0.23	25	0.11
ABSOLUTE CHANGE: improvement from MPS decommissioning									
2008	15km	1.6	0.0	6,385	0.003	1,285	3.25	1,436	6.5
2008	6km	0.8	0.0	5	0.009	1	0.01	4	0.02
RELATIVE CHANGE: improvement from MPS decommissioning as % of scenario with MPS									
2008	15km	5	0.0	62	62	75	75	48	48
2008	6km	10	0.0	10	10	5	5	14	14

It is important to note that hourly maxima in most cases are attributable to **extreme inversion situations**, characterized by extremely low (physical) mixing height as predicted by AERMET (minimum of 22 m for the physical PBL and very low wind speed of below 1 m/s) which is in all likelihood a model artefact. No measurements (meteorological observations) on vertical temperature profile and thus estimates of mixing height are available to test this assumption. The emission source responsible is Valletta harbour with very low (ship chimneys) emission heights. These effects are restricted to the immediate vicinity of the harbour. The scenario also indicate exceedances (hourly NO_x/NO_2) at the sensitive receptor location "Marsa Sport Club", but their number during any year simulated is safely below the allowable number of exceedances of 18.

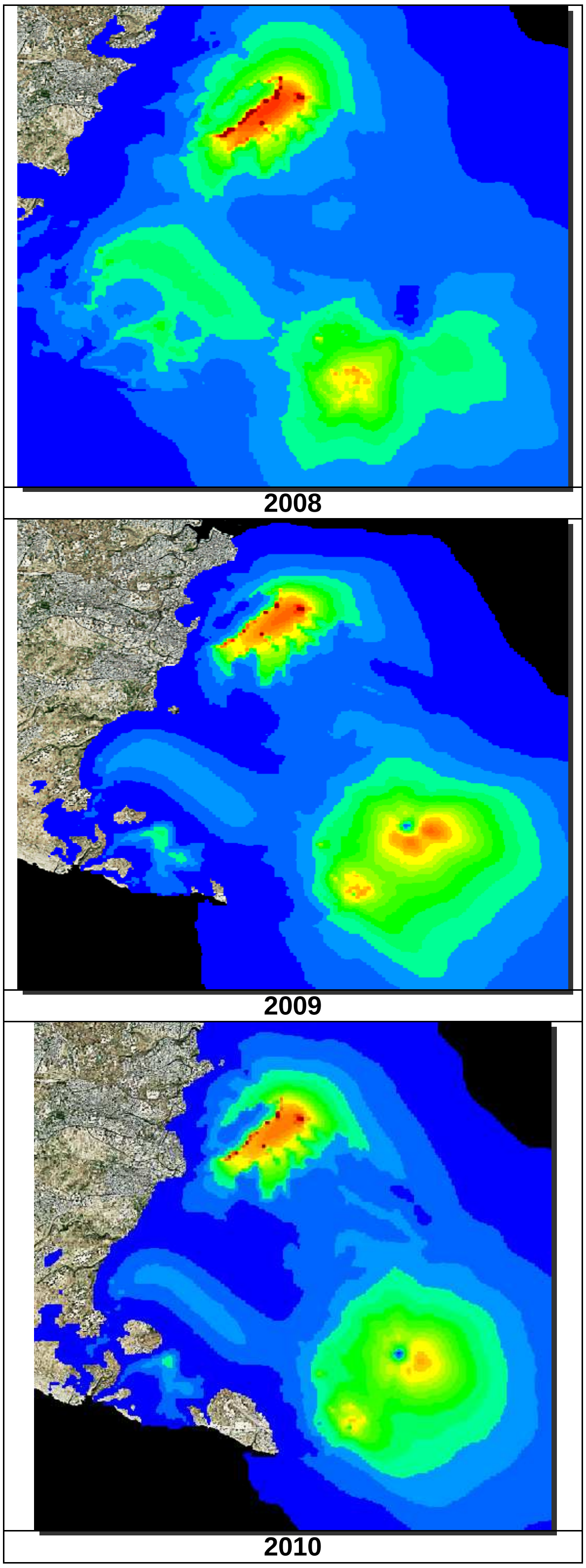


Figure 64. Annual average maxima for 2008 (top): 29.2 µg/m^3; 2009 (middle): 18.9 µg/m^3; and 2010 (bottom): 20.0 µg/m^3.

8. Comparison with limits in legislation.

While legislation addresses both concentration in the flue gas and ambient concentrations, the modeling study concentrates on ambient concentrations only. For the substances of concern, The Air Quality Framework Directive 2008/50/EC defines limit and target values as in Table 34.

Table 34. Limit values for ambient air quality parameters as defined by Air Quality Framework Directive 2008/50/EC.

substance	period	value	unit	comment
NO_2	hourly	200	µg/m3	not to be exceeded more than 18 times in a calendar year; limit value since 2010
NO_2	annual	40	µg/m3	
PM_{10}	daily	50	µg/m3	not to be exceeded more than 35 times in a calendar year; limit value since 2005
PM_{10}	annual	40	µg/m3	limit value since 2005
$PM_{2.5}$	annual	25	µg/m3	target value since 2010; limit value as of 2015
lead	annual	0.5	µg/m3	
cadmium	annual	5	ng/m3	target value as of 2012
arsenic	annual	6	ng/m3	target value as of 2012
nickel	annual	20	ng/m3	target value as of 2012
BaP	annual	1	ng/m3	target value as of 2012

Table 35. Hourly, daily, yearly (where applicable) limit value exceedances for ambient air quality parameters for the DPS Baseline scenario. Values highlighted in yellow indicate exceedances within the allowable limit. Values exceeding the tolerable amount of exceedances are highlighted in red.

DPS Baseline annual/hourly	NO_x/NO_2		PM_{10}		Cd	As	Ni	BaP
	Hour	year	day	year	year	year	year	year
DPS only, 2008								
DPS only, 2009	1							
DPS only, 2010								
DPS + BG, 2008	39							
DPS + BG, 2009	75							
DPS + BG, 2010	110							

Table 36. Hourly, daily, yearly (where applicable) limit value exceedances for ambient air quality parameters for the DPS Extension scenario. Values highlighted in yellow indicate exceedances within the allowable limit. Values exceeding the tolerable amount of exceedances are highlighted in red.

DPS Extension annual/hourly	NO_x/NO_2		PM_{10}		Cd	As	Ni	BaP
	hour	year	day	year	year	year	year	year
DPS only, 2008								
DPS only, 2009	2							
DPS only, 2010	3							
DPS + BG, 2008	39		4					
DPS + BG, 2009	76		6					
DPS + BG, 2010	110		6					

$PM_{2.5}$: even assuming a 100% $PM_{2.5}$ fraction in the PM_{10} values (as suggested by the few observations available), predicted annual average values are well below the target value of 25µg/m^3.

Compliance with air quality standards is summarized in the table below, the number within the color coded fields indicate the number of violations (grid point and hour: basis for comparison is the total number of possible violations within the 6 km radius around DPS. The illustrations below, that show that exceedances of hourly NO_2 standards (tier 1 comparison with NO_x concentrations) are very localized, in general outside the 6 km radius (influences mainly by the Marsa TPS) but also extremely variable in time.

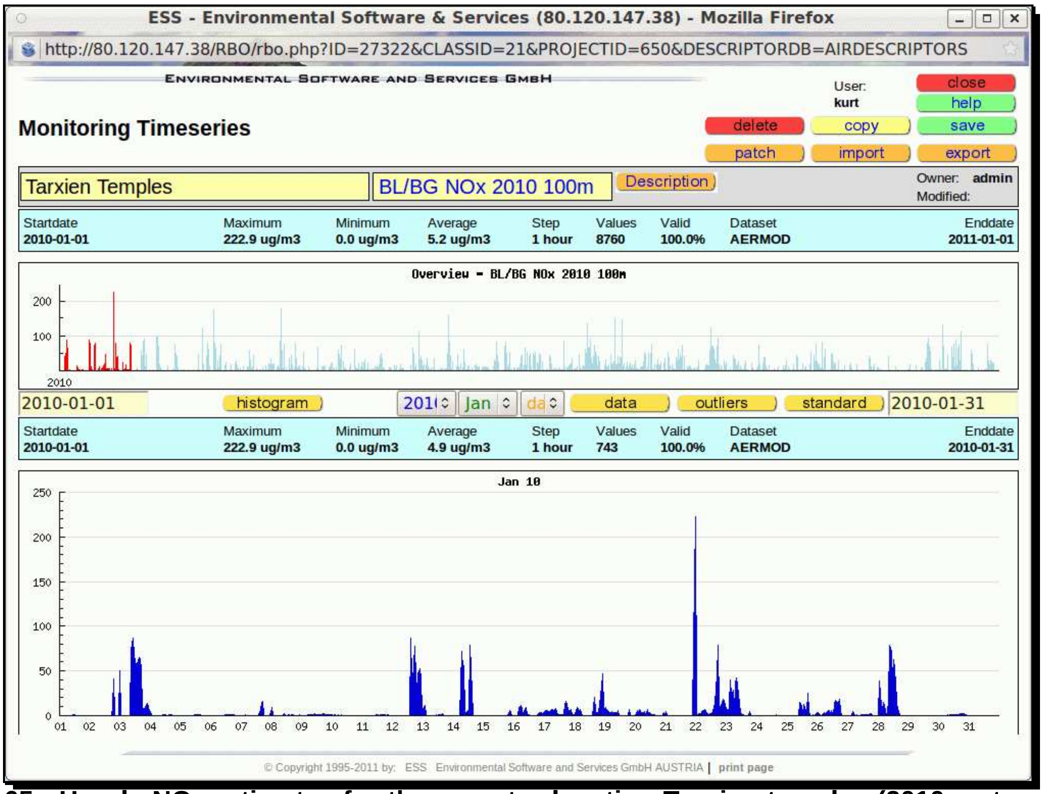


Figure 65. Hourly NO_x estimates for the receptor location Tarxien temples (2010 meteorology) showing temporal variability with a singular violation in January.

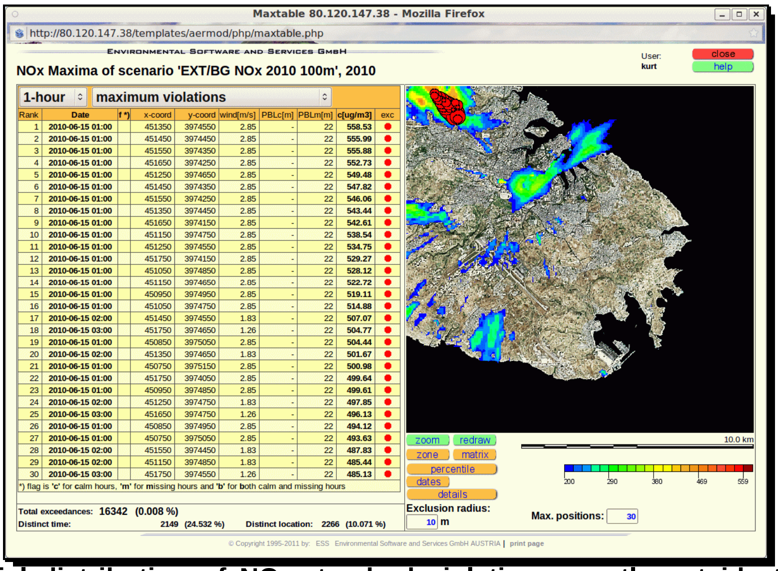


Figure 66. Spatial distribution of NO_2 standard violations mostly outside the 6km primary impact zone around the DPS. 2010 meteorology is used.

The spatial distribution of NO_2 standard violations (Figure 66) indicates the majority of violation around Valletta and outside the 6 km primary impact zone around DPS. The color coding starts at the hourly standard 200 µg/m3 (blue) and range to the predicted maximum of 559 µg/m3 (dark red); the red circles (NW corner of the map) indicate the position of the 30 highest hourly values predicted (2010 meteorology).

9. Limitations of study.

The basic limitations of the study results from several constraints:

- **Data availability and quality:** Limited availability and coverage (temporal, spatial) of data, primarily of emission data and monitoring data for model validation; due to the island location, there is a considerable variability of meteorological situations and thus observed or predicted ambient concentration of air pollutants at any given receptor locations. Only a long-term monitoring and/or modeling program can provide (statistically reliable) probabilistic estimates. A primary constraint however, is a reasonably complete and consistent, reliable emission inventory.

- **Model uncertainty:** limitations due to model selection, inherent assumptions, and configuration. Different models (Gaussian, Eulerian, Lagrangian, steady state and dynamic, at different resolutions and boundary conditions) will yield different results that can vary considerably. At the same time, systematic model validation is constrained by data availability and quality.

- **Stochastic problem:** inherently stochastic nature of the problem, which suggests the use of a probabilistic (long term, data redundancy, ensemble-based) approach as the "scientifically" (more) correct solution. This, however, implies considerable effort in both data collection and analysis.

- **Limited scope:** Like any other analytical study of this type, this raises a number of questions that are outside the scope of the assignment.

10. Summary and Conclusions

The model based analysis (AERMOD, regulatory Gaussian model) indicates the following:

All annual standards are met (NO_2/NO_x, $PM_{10}/_{2.5}$, metals and B[a]P throughout the 15 km model domain;

Short term standards (daily average) for PM_{10} are violated in very few cases, and are below the number of allowable exceedances (Directive 50/2008/EC: 35/year). Given that the DPS extension scenario assumes the worst case situation in which bag filters are not operational, and considering the abatement that will be in place once the DPS extension is fully operational, this already compliant situation can only be improved upon.

Short term standards for NO_2/NO_x (hourly, tier 1 approach comparing NO_2 standards with the computed NO_x concentrations) are violated above the limits for the number of exceedances allowed by Directive 50/2008/EC (18/year). These violations are however due to the cumulative impacts of overall (background) emissions outside the 6km impact zone around DPS, i.e., the MPS, harbours, airport, and other small sources. It is important to note that the MPS is a major contributor (70% of NO_x emissions). The decommissioning of part or all of the capacity at the MPS would make a large difference to violations as predicted for all background and combined scenarios. The DPS by itself on the other hand does not violate any limit/target values and contributes very marginally to target value violations. It is already in compliance with the very conservative values of 50% SCR efficiency and results show that it is difficult to improve upon target value exceedances via any changes to the extension. Higher stack heights may, in theory, displace combined impacts and result in worse interaction between the various emission sources at different locations. Furthermore, changes in target value violations are more likely to result from uncontrollable meteorological changes rather than any changes introduced via the DPS extension.

Note that the regulatory model AERMOD provides very conservative, “worst case” steady-state estimates for the hourly averages. Due to the relatively high observed levels of ozone, the AERMOD/OLM estimates for NO_2 do not differ from the computed NO_x values (Figure 67).

The parallel use of the 3D dynamic Eulerian model CAMx (with full photochemistry for direct NO_2 estimates) for a period of 960 hours (June 24 to August 1) at a 500 m resolution for the innermost domain shows a singular value of 201 $\mu g/m^3$ for the values extracted for the monitoring location Zejtun, and thus suggests fewer violations despite considering national and European (EMEP 2009) emissions and long-range transport as dynamic background.

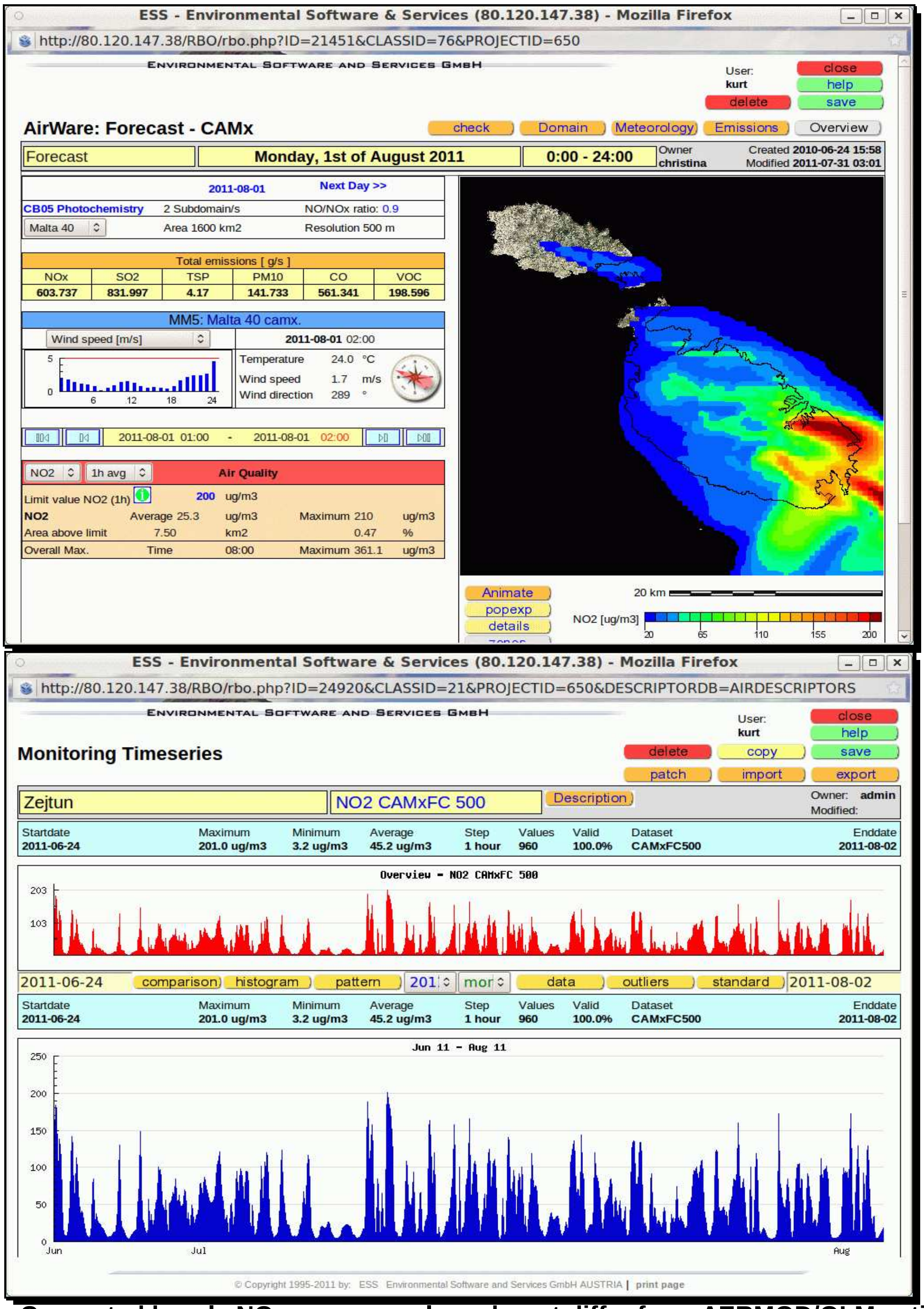


Figure 67. Computed hourly NOx average values do not differ from AERMOD/OLM estimates for NO_2.

Below we summarize again the compliance before and after the DPS capacity extension, excluding the traffic contributions.

(see above: while traffic (under the simplifying assumption and very limited data basis available) and considering a subset of the road network only must be expected to generate frequent exceedance of the hourly NO_2 standards, due to the steep (logarithmic) gradients and high resolution of the models used of 10m) these results are not directly compatible. When aggregated to the same 100m (hectare grid) resolution, traffic contributions are pro rata, i.e., below 10%.

Tables 37 and 38 below summarize the number of exceedances for short-term NO_x/NO_2 standards within the 6km immediately surrounding the DPS and the 15km area including other emitting sources such as the MPS. Note that while the maximum number of exceedances allowed for NO_2 is 18 per year, EU compliance regulations assume a small number of receptor/monitoring points. Results generated for the 6km and 15km areas, on the other hand, are generated for a large number of receptor points, due to the high spatial coverage of the models used. Therefore, in order to show normalised changes brought about by the installation of the DPS extension and show impacts independently of the number of receptors that are considered in this modelling study, the relative (%) increase of the expected violations presented in Table 39 should be considered and given particular attention when interpreting this report.

Table 287. NO_x/NO_2 hourly exceedances for DPS Baseline scenario.

DPS Baseline	total exceedances		distinct times		distinct locations	
NO_x/NO_2 hourly	6km	15km	6 km	15km	6km	15km
DPS only, 2008	**0**	**0**	**0**	**0**	**0**	**0**
DPS only, 2009	**1**	**1**	**1**	**1**	**1**	**1**
DPS only, 2010	**0**	**0**	**0**	**0**	**0**	**0**
DPS + BG, 2008	**39**	**9,853**	**21**	**379**	**29**	**2,993**
DPS + BG, 2009	**75**	**14,189**	**35**	**2,150**	**47**	**2,140**
DPS + BG, 2010	**110**	**15,633**	**46**	**2,142**	**81**	**2,253**
AVERAGE 2008-10	**75**	**13,225**	**34**	**1,557**	**52**	**2,462**

Table 38. NO_x/NO_2 hourly exceedances for DPS Extension scenario.

DPS Extension	total exceedances		distinct times		distinct locations	
NO_x/NO_2 hourly	6km	15km	6 km	15km	6km	15km
DPS only, 2008	**0**	**0**	**0**	**0**	**0**	**0**
DPS only, 2009	**2**	**2**	**2**	**2**	**2**	**2**
DPS only, 2010	**3**	**3**	**2**	**2**	**3**	**3**
DPS + BG, 2008	**39**	**10,316**	**21**	**382**	**29**	**2,997**
DPS + BG, 2009	**76**	**14,774**	**36**	**2,155**	**48**	**2,183**
DPS + BG, 2010	**113**	**16,342**	**48**	**2,149**	**84**	**2,266**
AVERAGE 2008-10	**76**	**13,811**	**35**	**1,562**	**54**	**2,482**

times: out of 8,760/8,784 hours
locations: out of 22,500 ha (15 km domain) and 11,310 ha (6km radius)

Table 39. Change in total exceedances and % exceedances resulting solely from the DPS Extension.

Change due to the DPS Extension NO_x/NO_2 hourly	total exceedances		distinct times		distinct locations	
	6km	15km	6 km	15km	6km	15km
AVERAGE increase of exceedances	**1 (1.3 %)**	**586 (2.2%)**	**1 (2.9%)**	**5 (0.3 %)**	**2 (3.8%)**	**20 (0.8%)**

1. Baseline scenarios:
   DPS baseline scenarios (138 g/s NO_x) shows almost complete compliance (with the exception a singular one hourly event, depending on the choice of meteorological input file and terrain correction); the results are consistent with the observed pattern (NO_2 example from Zejtun monitoring, showing a singular (one hour) violation in 2008 attributable to the meteorological conditions.

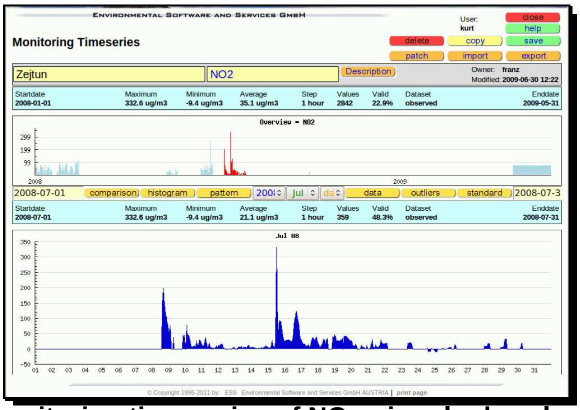


Figure 68. Zejtun monitoring time series of NO_2, singular hourly exceedance

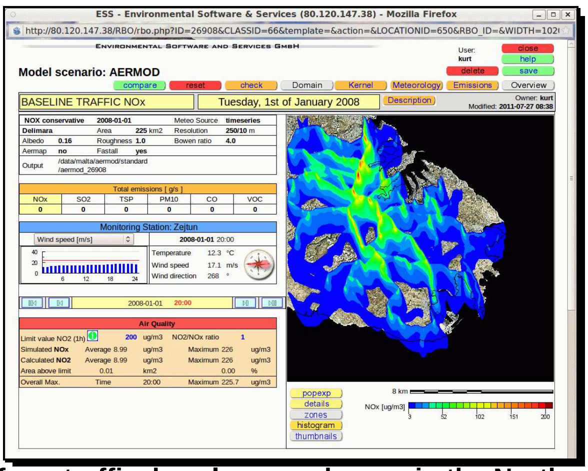


Figure 69 Simulated NO_x from traffic, hourly exceedances in the Northern part of the area around Valletta, corresponding to a higher road density

The baseline scenario together with the background emissions (primarily the MPS, airport, harbours), total NO_x emissions: 306 g/s) indicates compliance with all annual standards (NO_2, PM_{10}, metals, B[a]P) but an increase in the violations of short-term NO_2, hourly) standards.

Considering traffic, violation of NO_2 hourly standard is restricted to the immediate nearfield of the roads, and largely in the Northern part of the domain, around Valletta due to a higher road density.

2. Capacity extension:

The additional emissions of 34 g/s NO_x and 25 g/s PM_{10} increase the predicted ambient concentration in proportion: the Gaussian solution is linear in emissions, and obeys mass conservation laws. In terms of violations of standards, the picture is more complex, however:

- **Metal, B[a]P:** predictions for metals and B[a]P remain well under the annual target values for both baseline and extensions.

- **NO_2/NO_x:** predictions for NO_x remain again well below annual NO_2 limit, but while the frequency and extent of hourly violations increases for the scenario of the DPS considered alone, almost no increase for the scenarios including the background emissions is shown (the relative increase of emission over the entire domain in this case is only half as much !).

- **$PM_{10/2.5}$:** predictions for PM_{10} also stay well below the annual limit values (which also implies compliance for $PM_{2.5}$), but exceed the hourly standards on very few (2-4/year) instances, well within the allowable number of annual exceedances for PM_{10} (35/year).

- **Overall Compliance:** in both cases (NO_2/NO_x) **the planned capacity extension does not affect compliance with Directive 50/2008/EC**, as the allowable exceedances per year (18 for NO_2) are already more than exhausted in the baseline scenarios including the background emissions, and predicted concentrations for all other pollutants are expected to be below the applicable limit and target values defined in Directive 50/2008/EC.

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12. Appendices

Several hundred simulation runs generate a data volume of several GB of memory that is very difficult to present in any “hardcopy” format. All results, tabular and pictorial illustration are therefore available on the on-line tool. **Appendix A** includes the emission sources data used in the model**.**

APPENDIX A

Emission Sources Data Used in the Model

Data Type	**Source**	**Names of data files / sources of information used**
Data from Delimara Power Station	Enemalta	DPS data
		Concentrations 2009-2010-2011 includijng flows
		DPS Windrose 2010
		stack properties DPS
		Wind data 2010
		HFO Spec May 2011
		Fuel delivery specifications
		GAS OIL SPEC May 2011
		DPS OCGT conc & load data
		GT3A 2009 concentrations
		DPS new plant data
		DB4-XZ-004(bLOCK 4)_DPS New
		Non-technical description_DPS New
		The Proposed Variations_DPS new
		DPS P3 06 emissions waste_DPS New
		DPS P3 12 Airborne Emissions Generated
		DPS New Plant Block Plan
		DPS New plant exhaust gas monitoring
		stack properties DPS new plant
		Revised Original Appendix 1_110718 air emissions Application for variations to DPS IPPC Permit: New Plant Appendix 1 (Rev A – Extract) Comparison of different operational conditions
		Data from Enemalta DPS Jun 11 reply
		Enemalta Report of Stack Air Emissions Monitoring October 2010
Data from Marsa Power Station	Enemalta	MPS data
		Flow data M1 & M2
		Flow data M3 & M4
		Data from Enemalta MPS June Reply
NO_2 Diffusion Tube data	MEPA	NO2 data
		Zurrieq data
PM data	MEPA	PM ZTN 2010
		Validated Zejtun data 2008
		Validated Zejtun data 2009
Traffic Fleet Distribution data	National Statistics Office	NSO Motor Vehicles Q1.2011(online available)
Population data by locality	National Statistics Office	Demographic Review 2009_NSO Malta (online available)
Emissions information	WasteServ Malta	Att 7 - Inputs - Outputs 2008
		DOC
		gp6
		Incinerator 2010 (pdf)
		Incinerator 2010 (excel)
		manual1
		MTTF Inputs-Outputs 2009
		Wasteserv Incinerator A4 Brochure revised
		WSM MTTF Daily Averages fullexport_daily
		WSM MTTF Hourly Averages fullexport
Airport Flight Schedules	MIA	Aircraft Types 2006-2010
		Aircraft Movements_Malta International Airport

Emissions information	Oil Tanking Malta	Information provided via email correspondance with MEPA
Freeport and Oil Tanking ship schedules	TM	TM stats 1507
Freeport ship movement information	Freeport	Information provided via email correspondance with Ecoserv
Cruise & Ferry Schedules	Valletta Waterfront	[Online available] http://www.vallettawaterfront.com/